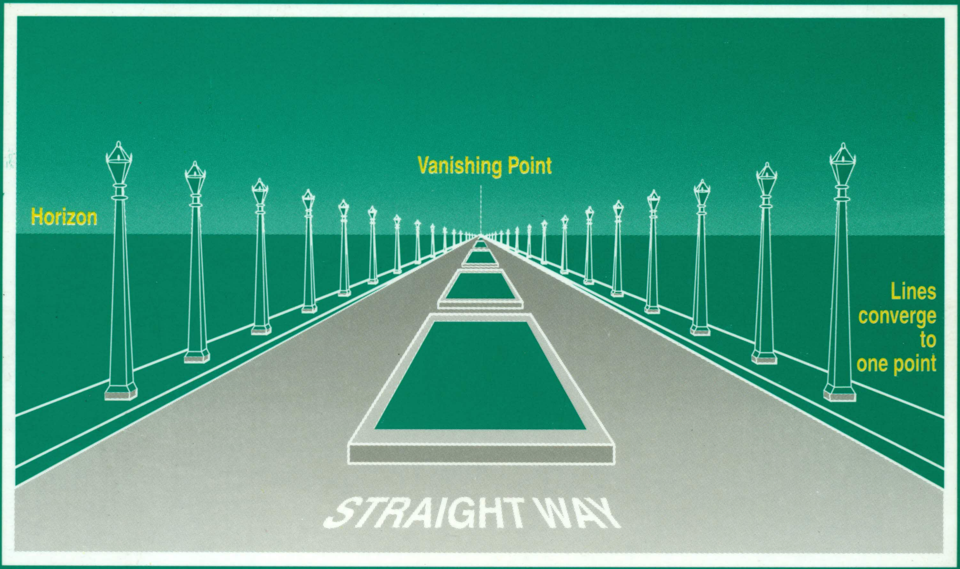
Beginner's Guide to

Engineering Drawing



One Point Perspective

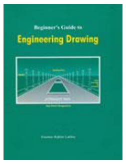
Enamur Rahim Latifee

Dear Student,

This book is for you, the beginner in Engineering Drawing. I tried, to the best of my capability, to cover the basic things and explain in as simple a way as I could, so that you find it attractive and easy. The information is available on the internet and free to access but in a few cases you may not be able to access, unless you are authorized. I tried to pick up the easier aspects from the available web based information. Sometimes I compiled the information from different sources to make ideas even clearer. Putting together this book was a learning process for me as well. Please do try to comprehend the book yourself as the book is meant for the self-starter. If you cannot follow it, then ask those who know the subject. In that case, your reward is double, as you have put an extra effort to learn.

All over the world, in colleges and universities, engineering drawing is offered as a basic course to various branches of engineering and technology, with titles like Engineering Drawing or Drafting or Technical Drawing or Engineering Graphics. Although this book is exclusively written for the students in my country, Bangladesh; I have made an effort to hold its universal appeal. Do not be misled that all the drawings presented here are my work. No, they are not! Except for a few, and others by students like you, who volunteered, and the rest is taken from the internet. There is no need to reinvent the wheel. I only gathered the necessary wheels and other body parts to form a suitable vehicle, for a novice to ride and explore. I strove to bring all the necessary information required for such an introductory course in this book, so that both the student and the teacher get the benefit. That is the core purpose of this book. Feel free to copy and distribute the information here; photocopy, scan or in any other form, to spread the knowledge. However, if you introduce any changes in this book then it will be your contribution. Please forgive and ignore if you find any mistakes in the book.

Dr. E. R. Latifee



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Chapter 1

Introduction

1.1 How Much Do We Know?

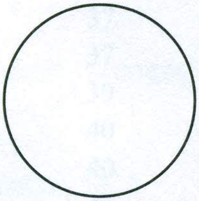
Think of a library. It can be defined as a collection of recorded knowledge. How much do we know of the recorded knowledge that is available only in one of the libraries on the surface of the earth? Isn't it like a drop of water in a sea? Above that, it is only what we could gather. Yet, if we consider what unknown, yet to discover for the human being is; then all the libraries on the surface of the earth combined, would become a drop in a sea that is equivalent to seven times and more than the previous sea.

Our knowledge amount to nothing except a little, but we are eager to learn and that's why you are reading the book. Look at the example, do you know that the earth's magnetic field undergoes periodic reversals of its polarity (North becomes South and vice versa) and that the last reversal occurred some 780,000 years ago?[1] There is a wise saying; *to acknowledge that you do not know, is one third of the knowledge.* However, it's significant that we came into being without knowledge otherwise we would not appreciate seeking knowledge. There is a wise saying; *to comprehend one thing you need the opposite.* Think of the examples, unless you were sick, you would not appreciate the sound health, if you were not starving, you would not appreciate the food, if there was no night, we would not appreciate the day, and if there was no day, we would not appreciate the night.

1.2 How Do We Communicate?

All the moving creatures that are alive use some ways to communicate, to exchange ideas and views or to express something, or to learn or to impart knowledge. Indeed, all the living species that can move are classes like the human being, but we are not given the power to comprehend their language. Do you know that human being can give lectures without a word? In one occasion, there was a lecture among others without a single word, yet she delivered the message like other speakers but with some movements and none could grasp the message. Could you figure it out? It was for the deaf and dumb. And there are methods to communicate with the blind ones. Sometimes, you may notice little dots on the floor number buttons inside the lift (elevator). Do you know for what reason the dots are there? These dots are arranged in a way so that the blind could recognize the number.

1.3 Engineering Drawing is a Way of Communication



Look at the figure on your right side. What do you think? Think again. How do you reflect? Isn't it obvious that it is a circle? Yes, you are right. It is similar to a circle or a ring. Yet it could be other things. It could be a ball, or the sun or the moon or something else. Now it must be puzzling, and therefore we need more information to be certain.

For example,

if someone had written some unseen words or letters without any grammar and moreover they are not even in the dictionary, then could anyone be able to understand it?

Therefore, we need a standard graphical language for Engineering Drawing with all the grammatical rules and vocabulary and other standards so that anyone with knowledge could understand. Now look at some standard definitions.

Engineering Drawing

> *"Engineering drawing is a formal and precise way of communicating information about the shape, size, features and precision of physical objects* [52]*."*
>
> *"A graphical language used by engineers and other technical personnel associated with the engineering profession. The purpose of engineering drawing is to convey graphically the ideas and information necessary for the construction or analysis of machines, structures, or systems."*[2]
>
> *"Drafting also spelled draughting, also called engineering drawing is a graphical representation of structures, machines, and their component parts that communicates the engineering intent of a technical design to the craftsman or worker who makes the product."*[3]
>
> *"An engineering drawing is a type of drawing that is technical in nature, used to fully and clearly define requirements for engineered items, and is usually created in accordance with standardized conventions for layout, nomenclature, interpretation, appearance (such as typefaces and line styles), size, etc. Engineering drawings are often referred to as 'blueprints.' However, the term is an anachronism, and is due to the fact that most copies of engineering drawings were formerly made using a chemical printing process that yielded graphics on blue-colored paper."*[4]
>
> *"Engineering Graphics (EG) is the language used by engineers to communicate the ideas and information necessary for the construction of engineering devices and systems."*[5]

Main Drawing Equipments

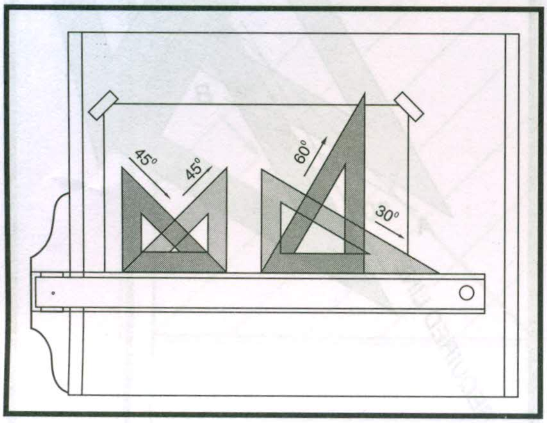
Now you need to start doing some drawings. Therefore gather the following items

- Drafting pencils or Lead pencils [2B and HB]
- Set Squares [i.e., 30° - 60° drawing triangle and 45° drawing triangle]
- Compass, dividers and card board scale (Optional)
- T square [i.e. "T" shape scale, 32" standard available in Bangladesh]

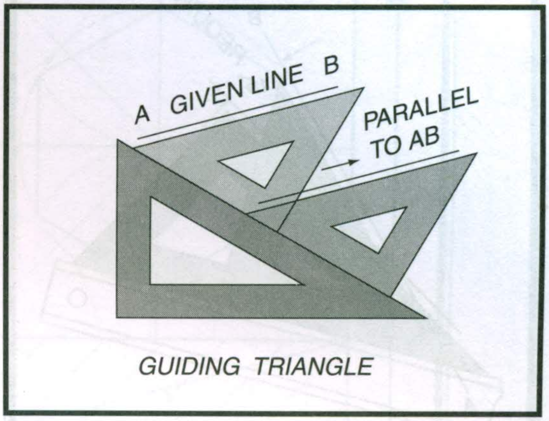
1.4 Make Practice with the Drawing Equipments

The following sketching techniques are courtesy of a drawing course material available on the internet[6].

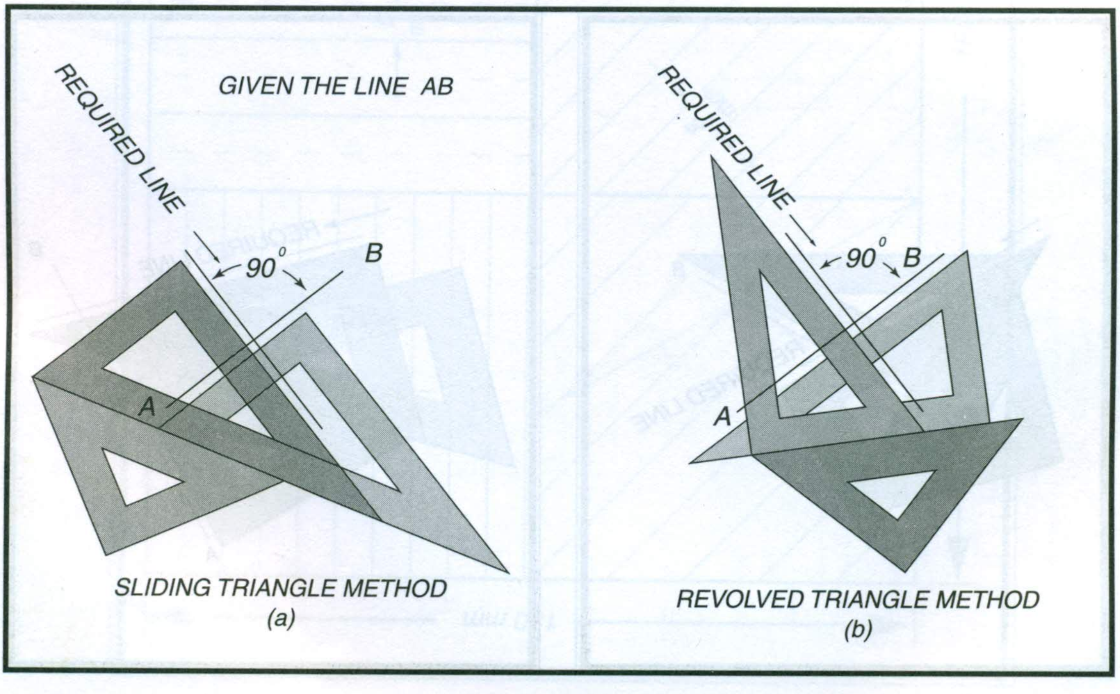
Inclined Lines



Parallel Lines



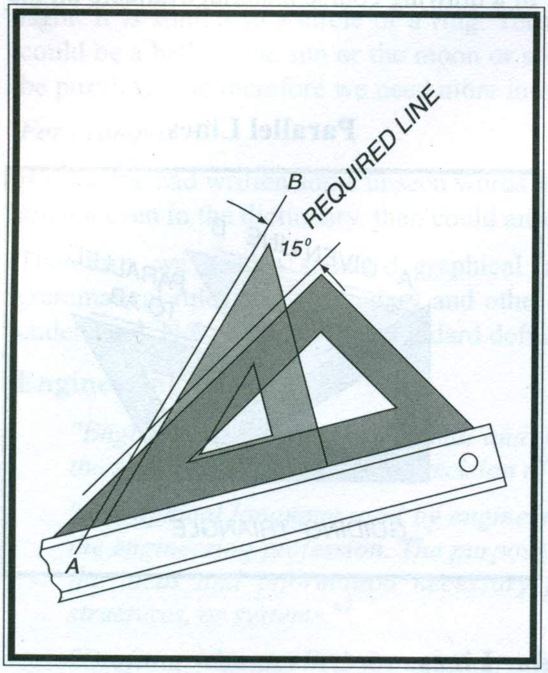
Perpendicular Lines

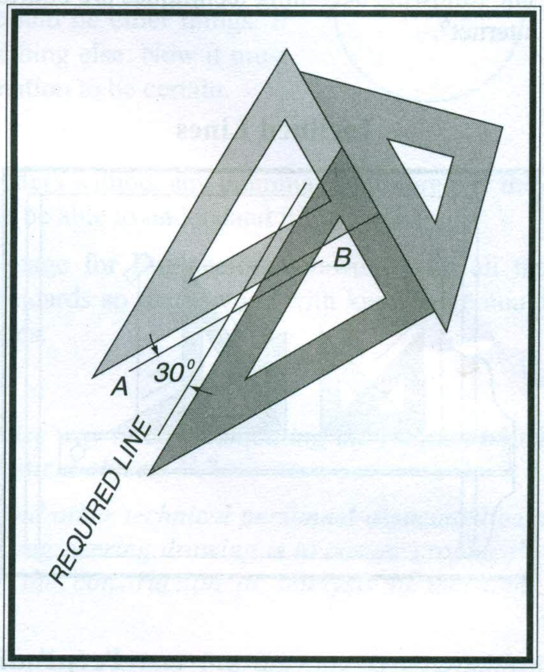


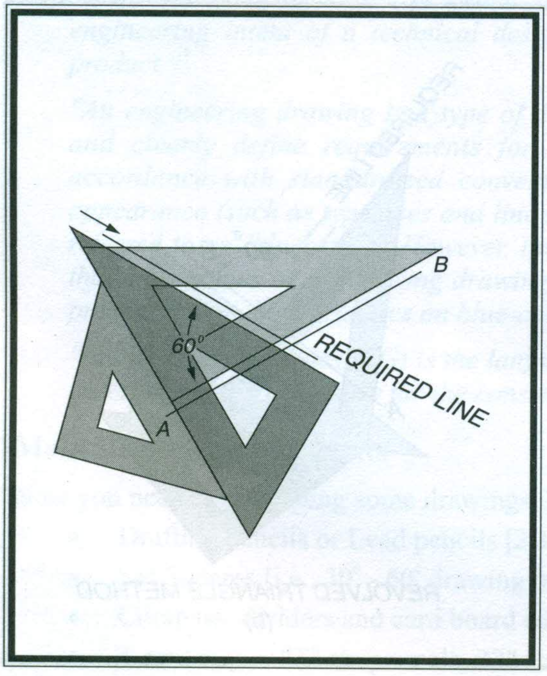
SLIDING TRIANGLE METHOD
(a)

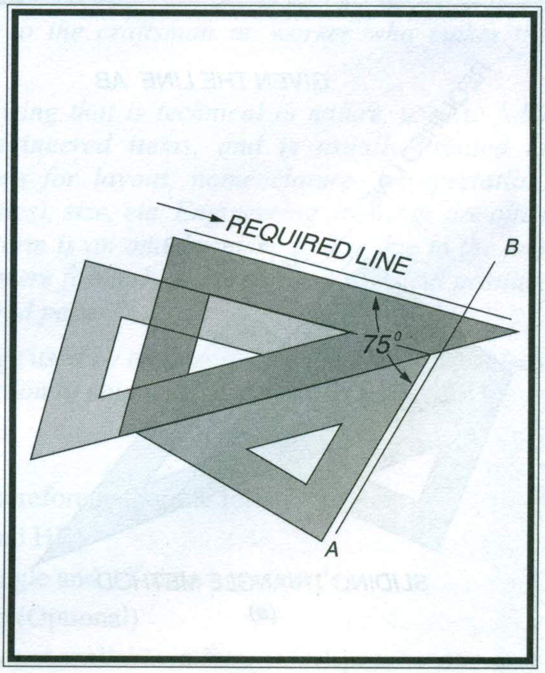
REVOLVED TRIANGLE METHOD
(b)

Incline Lines Making 15°, 30°, 45°, 60°, or 75° with an Oblique Line



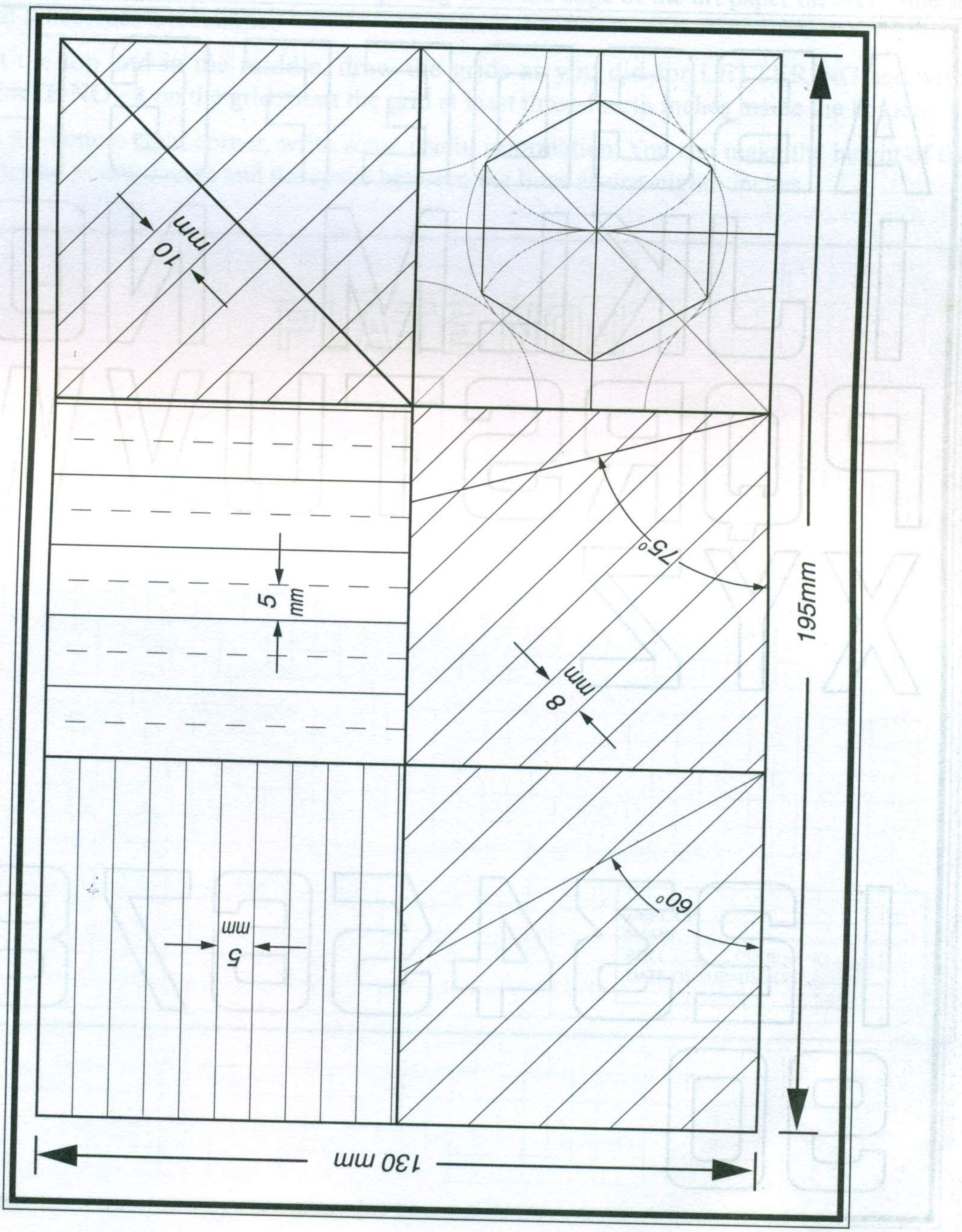






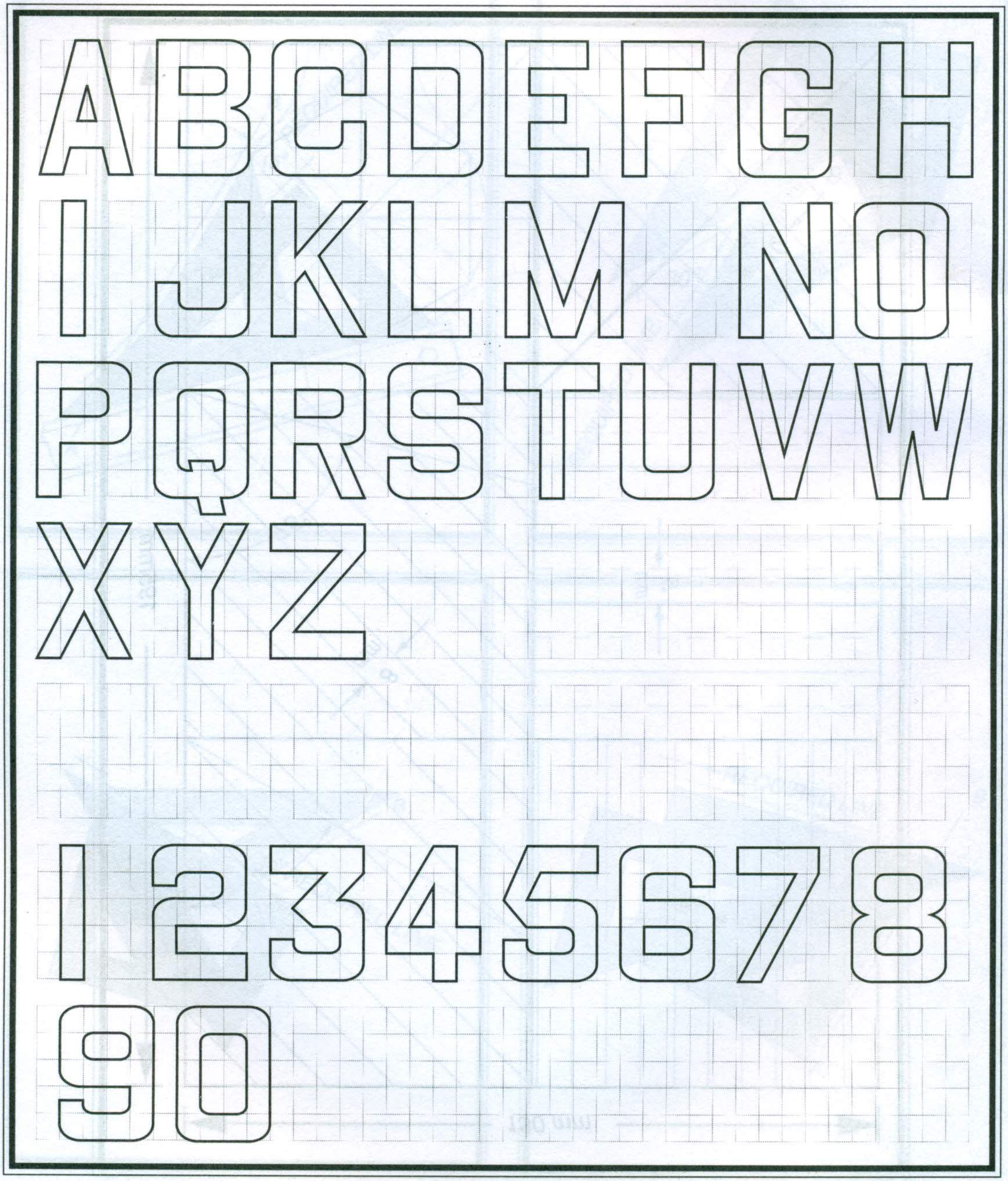
Exercise :

The following one[7] is a good exercise to gain experience with the equipments. Use "*HB Pencil*" to construct the formation and then use "2B" to draw the final drawing. You could do it on a piece of white paper or buy a drawing book. Do not be afraid about the exercise.



1.5 Lettering

A student like you did the following letters and numbers. Try with one-fourth (0.25) inches distance (technically it is called spacing) between the lines, in both the directions (i.e. X and Y axes).



1.6 Drawing on Art Paper

1. Get an art paper. Normally they are available in sizes 28 inches by 22 inches.
2. You can divide the art paper into two pieces, if it is easier to work.
3. Draw border lines with half inches spacing from the edge of the art paper on every side so that it becomes a rectangle.
4. At the top and in the middle, draw the grids as you did for LETTERING and write **PLATE NO - 1** on the grid. Start the grid at least three-fourth inches inside the border.
5. At the bottom right corner, write some useful information. You can make the height of the lettering as one-fourth and the space between the lines as one-eighth inches.

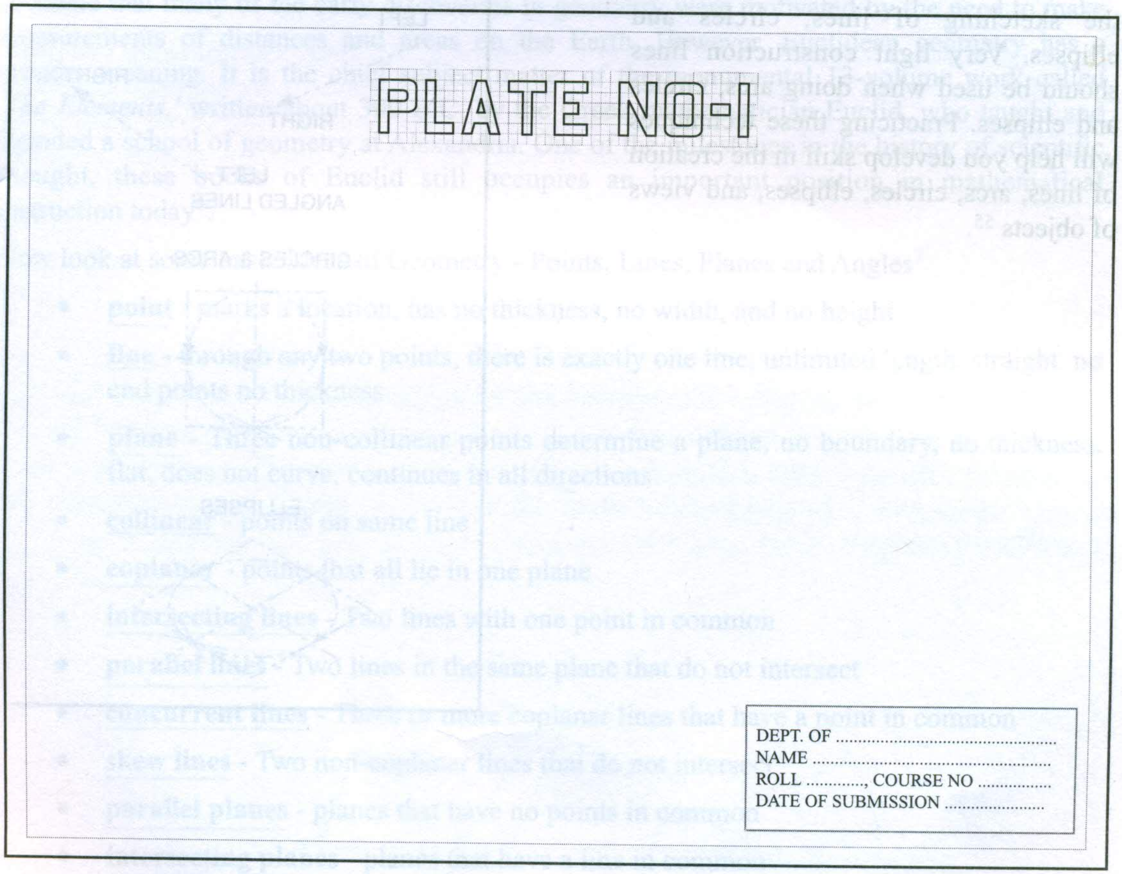
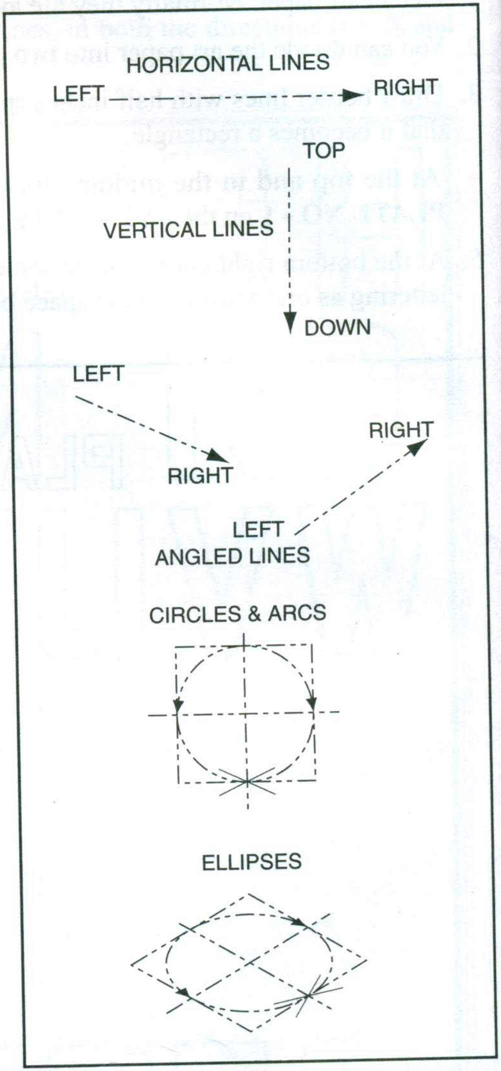


PLATE NO-I
DEPT. OF ....
NAME ....
ROLL ...., COURSE NO ....
DATE OF SUBMISSION ....

1.7 Sketching Techniques

The ability to create fast, understandable views of objects with only a pencil and a piece of paper is extremely important to being successful as an engineer, designer, architect, builder, manufacturer or craftsman. All objects are composed of lines: horizontal lines, vertical lines, angular lines, circular lines, arcs and ellipses. The procedures shown here describe the movement of your hand for the sketching of lines, circles and ellipses. Very light construction lines should be used when doing arcs, circles and ellipses. Practicing these techniques will help you develop skill in the creation of lines, arcs, circles, ellipses, and views of objects [55].



Chapter 2

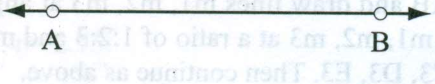
Review of Geometry

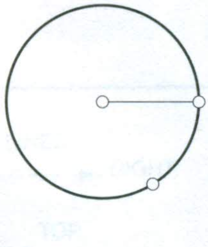
2.1 Geometry

The word geometry is derived from two Greek words meaning earth measurement. It seems probable that many of the early discoveries in geometry were motivated by the need to make measurements of distances and areas on the Earth. However, Euclidean geometry has a broader meaning. It is the chief subject matter of the monumental 13-volume work called *'The Elements,'* written about 300 B.C. by the Greek mathematician Euclid, who taught and founded a school of geometry at Alexandria. One of the milestones in the history of scientific thought, these books of Euclid still occupies an important position in mathematical instruction today[6].

Now look at some basic Ideas of Geometry - Points, Lines, Planes and Angles[7]

- **point** - marks a location, has no thickness, no width, and no height
- **line** - through any two points, there is exactly one line, unlimited length, straight, no end points no thickness
- **plane** - Three non-collinear points determine a plane, no boundary, no thickness, flat, does not curve, continues in all directions
- **collinear** - points on same line
- **coplanar** - points that all lie in one plane
- **intersecting lines** - Two lines with one point in common
- **parallel lines** - Two lines in the same plane that do not intersect
- **concurrent lines** - Three or more coplanar lines that have a point in common
- **skew lines** - Two non-coplanar lines that do not intersect
- **parallel planes** - planes that have no points in common
- **intersecting planes** - planes that have a line in common
- **segment** - AB set of all points A,B and all points between A and B





- **circle** - set of all points equidistant from a center point
- **acute** - less than a 90 degree angle
- **right** - 90 degrees
- **obtuse** - greater than 90 degrees
- **Oblique Angle**[8] - An angle that is not a right angle.

2.2 Two Dimensional Geometric Constructions

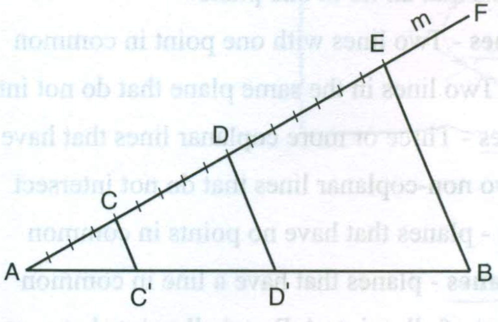
Do you remember triangles, rectangles, squares and other geometric figures? All of them are two- dimensional (2-D). To define a point on 2-D, you need 'X' and 'Y' coordinates (i.e. two measurements). It is also called plane geometry, since they all lie in one plane.

There are different ways to draw common geometric figures. Here, the following methods[9] are not hard as examples. However, some of these graphical solutions are common and some are not. As discussed earlier, Greek mathematician Euclid around 300 BC (Over 2300 years ago!) wrote thirteen books on geometry and in Book IV, you can find how to draw a regular hexagon with straightedge and compass.[9]

2.2.A. The Straight Line and Its Division

1. ***To Divide a Line Segment into a Given Ratio***

Let AB represent the given line segment, and let the given ratio be 4:5:7. Draw line "m" (i.e. line AF) through point A and at any convenient angle with AB. On "m" lay off distances AC = 4 units, CD = 5 units, DE = 7 units. Draw BE and then draw lines through C and D parallel to BE, cutting AB in points C' and D', which determine the required segments of AB.



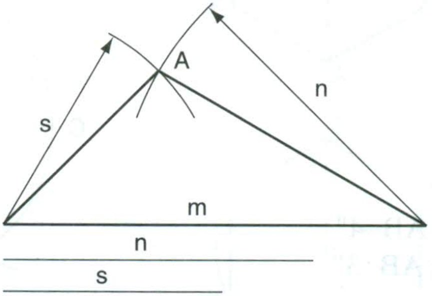
Exercise :

Take any line length AB and draw lines m1, m2, m3 at angles 30, 60 and 90 degrees to AB, then cut the lines m1, m2, m3 at a ratio of 1:2:3 and mark the points as C1, D1, E1, and C2, D2, E2, and C3, D3, E3. Then continue as above.

2.2.B. The Construction of Triangles and Regular Polygons

1. *To Construct a Triangle with Known Lengths of the Sides*

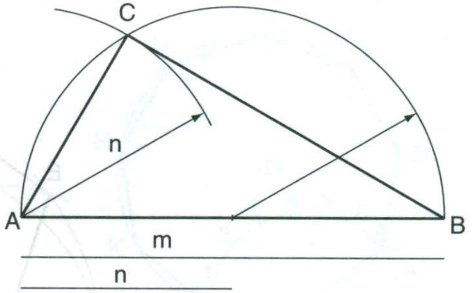
Suppose m, n, and s are the given lengths. With the end points of m as centers and radii equal to n and s, respectively, draw intersecting arcs, locating point A. Join A with the end points of m to complete the construction of the triangle. Is it possible to construct a triangle with 7, 3.5 and 3 inches as the lengths?



Exercise : Take m= 5″, n= 4″, s =3″
Take m= 4″, n= 3″, s =2″

2. *To Construct a Right Triangle when the Lengths of the Hypotenuse and One Side are Known*

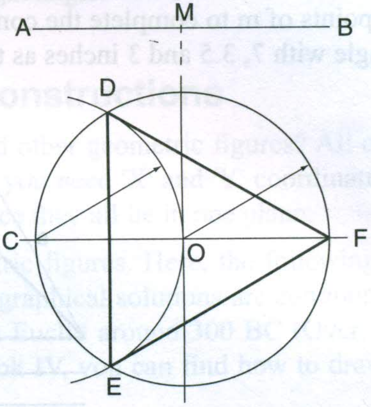
Let line m and n represent the given lengths. Construct a semicircle with diameter AB equal to length m. With A as center (could use B) and radius equal to length n, draw an arc cutting the semicircle at point C. Triangle ABC is the required right triangle. Why is this true?



Exercise : Take m= 6″, n= 2.75″
Take m= 4″, n= 1.5″

3. *To Inscribe an Equilateral Triangle within a Circle Having a Given Diameter, AB*

With center O and radius equal to AM (M is midpoint of AB), draw the circle. With C as center and the same length of radius, draw an arc cutting the circle in points D and E. Join points D, E, and F. The required triangle is DEF.



Exercise : Take AB=4"
Take AB=3"

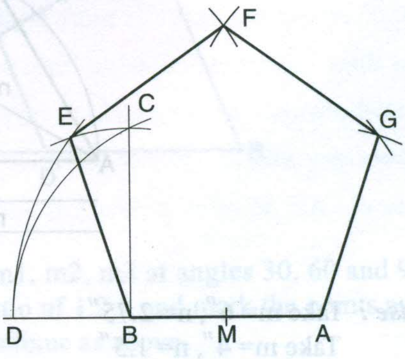
4. *To Construct a Regular Pentagon when the Length AB of the Sides is known*

i) First construct BC = AB, and BC is perpendicular to AB.

ii) With M (midpoint of AB) as center and MC as radius, draw an arc cutting AB extended at point D.

iii) Now with A as center and AD as radius, draw an arc; and, with B as center and radius BA, draw an intersecting arc to locate point E. Line BE is a side of the regular pentagon.

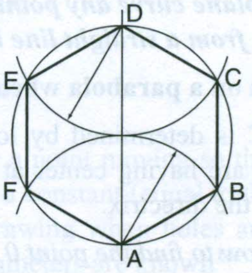
iv) Then with B as center and AD as radius, draw an arc; and, with A as center and radius BA, draw an intersecting arc to locate point G. The construction for locating point F is fairly obvious. ABEFG is the required pentagon.



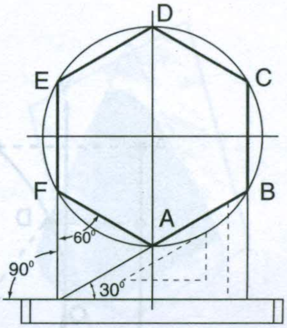
Exercise : Take AB = 2″
Take AB = 1.5″

5. *To Inscribe a Hexagon within a Given Circle*

With A and D as centers and a radius equal to the radius of the circle, draw arcs which intersect the given circle in points B, F, C, and E. The required hexagon is ABCDEF.

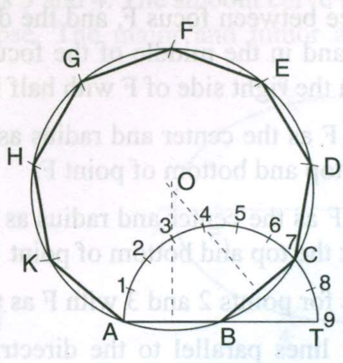


An alternative construction is shown.



6. *To Construct a Regular Polygon Having n Sides*

The polygon in this example is a nonagon (nine equal sides) and AB is the given length of each side. With B as center and AB as radius, describe a semicircle, and by trial divide it (i.e. the semicircle) into nine equal parts. Starting from point T, locate the second division mark, C. Locate point 0, the center of the circumscribing circle. (Finding the intersection of the perpendicular bisectors of AB and BC easily does Point 0.) Draw the circle with center O and radius OA and complete the nonagon.



General Rule: *To find the summation of angles in any polygon, use* **$(2N-4) \times 90^0$** *where, N is the number of sides.*

2.2.C. Conic Sections

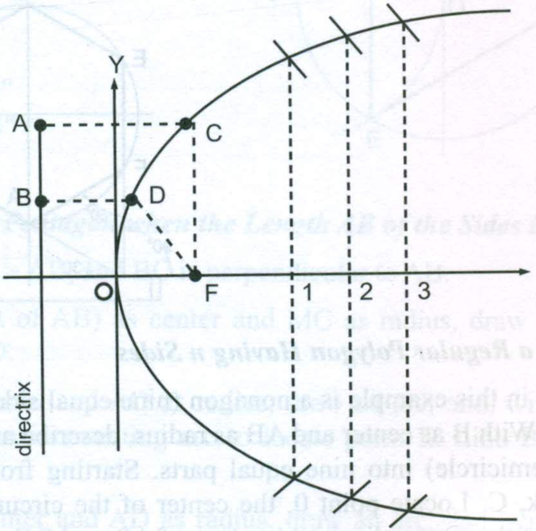
Parabola

A parabola is a plane curve any point of which is the same distance from a point called the focus as it is from a straight line known as the directrix[10].

To locate points on a parabola when the focus, F, and the directrix, AB are given

Point such as C is determined by locating the intersection of any line parallel to the directrix and an arc having center at F and a radius equal to the distance between the parallel line and the directrix.

Could you tell how to find the point 0 on the following figure?



Exercise :

Take the distance between focus F, and the directrix, AB as two inches. Therefore point O is on X-axis and in the middle of the focus F, and the directrix, AB. Now take three points (1,2,3) on the right side of F with half inches interval.

1. Then, take F as the center and radius as the distance between F and AB, draw arcs on just the top and bottom of point F.
2. Then, take F as the center and radius as the distance between point 1 and AB, draw arcs on just the top and bottom of point 1.
3. Repeat this for points 2 and 3 with F as the center.
4. Now draw lines parallel to the directrix through points F, 1,2 and 3 to find the intersections on the top and bottom of the X-axis. Join all these points and pass through point O to complete the parabola.

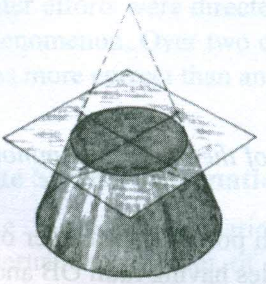
Ellipse:

The ellipse may be defined as the locus of all coplanar points, the sum of whose distances from two fixed points (foci) is a constant.

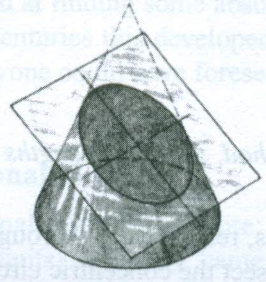
More notes on ellipse.

Mathematically the ellipse is a curve generated by a point moving so that at any position the sum of its distances from two fixed points (foci) is a constant (equal to the major diameter). It is encountered very frequently in orthographic drawing when holes and circular forms are view obliquely. Ordinarily, the major and minor diameters are known[11]

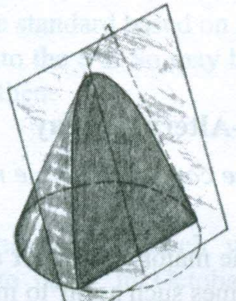
Conic Sections :



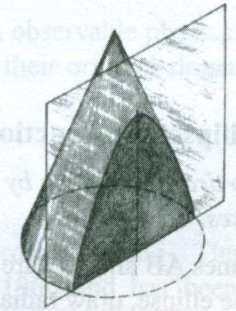
Circle



Ellipse



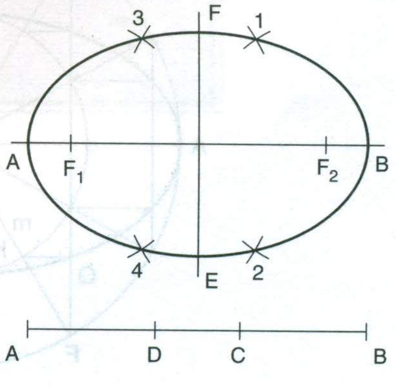
Parabola



Hyperbola

To construct an ellipse when the foci F_1 and F_2 and the constant distant AB are given. With F_1 as center and radius AC (any portion of AB), an arc is drawn. Now with F_2 as center and radius CB, an arc is drawn intersecting the first arc in points 1 and 2, which are two points on the ellipse.

This construction is repeated for the location of additional points. For example, with F_1 as center and radius AD, an arc is drawn, and with F_2 as center and radius DB an intersecting arc is drawn, thus locating two additional points 3 and 4. The smooth curve passing through these points and others (not shown) is the ellipse. The major and minor axes are AB and EF, respectively.



Exercise :

Take AB as 4 inches and F_1, F_2 half inches from A,B respectively. Also, take AD=1.5" and BC=1.5". Find the points 1,2,3,4 as showed above.

Exercise :

Take

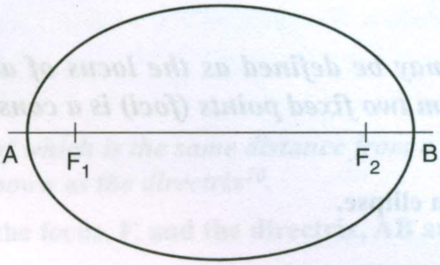
$AB = 4''$

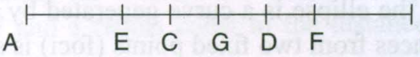
$AF_1 = BF_2 = 0.5''$

$AC = BD = 1.5''$

$AE = BF = 1''$

$AG = BG = 2''$



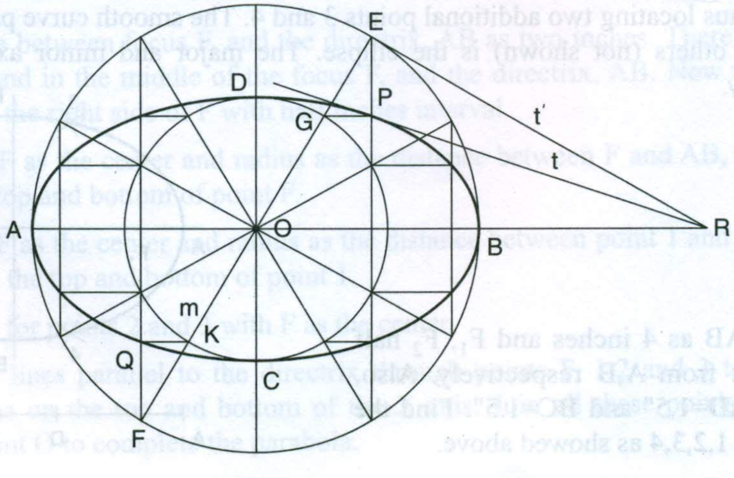


Ellipse Construction-Alternate Way

To draw an ellipse by the concentric circle method, given the lengths of the major and minor axes.

Lines AB and CD are the major and minor axes, respectively. Through point O, the center of the ellipse, draw radial lines such as 'm' to intersect the concentric circles having radii OB and OC in points E, F, G, and K. Through points E and F draw vertical lines to intersect the horizontals drawn through G and K, in points P and Q, which are two points on the ellipse. Repeat this construction for additional points and then draw a smooth curve through these points to form the ellipse.

The tangent, t, at point P passes through point R, which is the intersection of the tangent t' at point E of the major circle and the major axis extended.



2.3 A Brief History of Measurement

One of the earliest types of measurement concerned that of length. These measurements were usually based on parts of the body. A well documented example (the first) is the Egyptian cubit which was derived from the length of the arm from the elbow to the outstretched finger tips. By 2500 BC (4500 years from today!) this had been standardized in a royal master cubit made of black marble (about 52 cm). This cubit was divided into 28 digits (roughly a finger width) which could be further divided into fractional parts, the smallest of these being only just over a millimeter.

In France the metric system officially started in June 1799 with the declared intent of being 'For all people, for all time'. **The unit of length was the meter which was defined as being one ten-millionth part of a quarter of the earth's circumference. Could you calculate the earth's circumference?**

Later efforts were directed at finding some absolute standard based on an observable physical phenomenon. Over two centuries this developed into the **S I**. So may be their original slogan was more correct than anyone could have foreseen then.

The System International [S I]

"Le Systeme international d'Unites" [Note: These are French words, meaning- The international system of units] officially came into being in October 1960 and has been officially recognized and adopted by nearly all countries, though the amount of actual usage varies considerably. It is based upon 7 principal units, 1 in each of 7 different categories -

Category	*Name*	*Abbrev.*
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	Kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

The U K (Imperial) System of Measurements

The old Imperial (now UK) system was originally defined by three standard measures - the yard, the pound and the gallon which were held in London. They are now defined by reference to the S I measures of the meter, the kilogram and the liter. These equivalent measures are exact.

1 yard	= 0.9144 meters	- same in US
1 pound	= 0.453 592 37 kilograms	- same in US
1 gallon	= 4.546 09 liters	- different in US

Notice particularly that the UK gallon is a different size to the US gallon so that NO liquid measures of the same name are the same size in the UK and US systems. Also that **the ton (UK) is 2240 pounds while a ton (US) is 2000 pounds.** These are also referred to as a **long ton** and **short ton** respectively[12].

2.4 Coordinate System

A system for specifying points using coordinates measured in some specified way. The simplest coordinate system consists of coordinate axes oriented perpendicularly to each other, known as *Cartesian coordinates*. Depending on the type of problem under consideration, coordinate systems possessing special properties may allow particularly simple solution. In three dimensions, so-called right-handed coordinate systems are usually chosen by convention, although left-handed coordinate systems are also encountered occasionally [13]

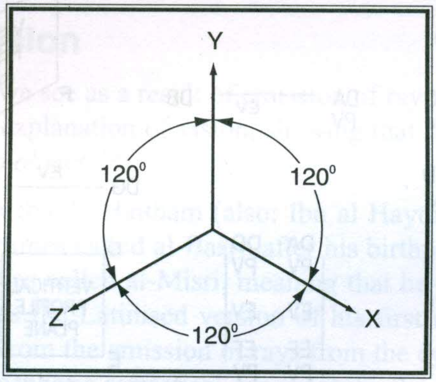
3-D Coordinate System is same as for 2-D, with the addition of a z-axis. ***For each orientation (Right-handed or Left-handed), the thumb points in the +x direction, the pointer finger is +y, and the middle finger is +z.)***[14]

3-D visualization

3-D Visualization skills are important in a variety of careers: engineering, architecture, chemistry, mathematics, sheet metal working, etc.[15]

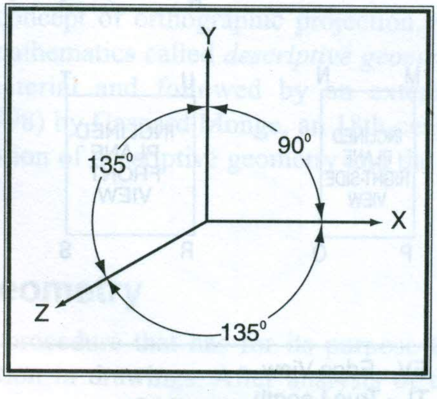
3-D Coordinate Systems Used for Visualization

Isometric Axes: Isometric means "equal measurement". In the Isometric system, each pair of axes meet at 120^0. Thus, the name isometric from the Greek iso- meaning the same. When objects are drawn using isometric axes, all surfaces of the object will appear distorted. In other words, squares will appear as parallelograms, and circles will appear as ellipses.



Isometric Axes

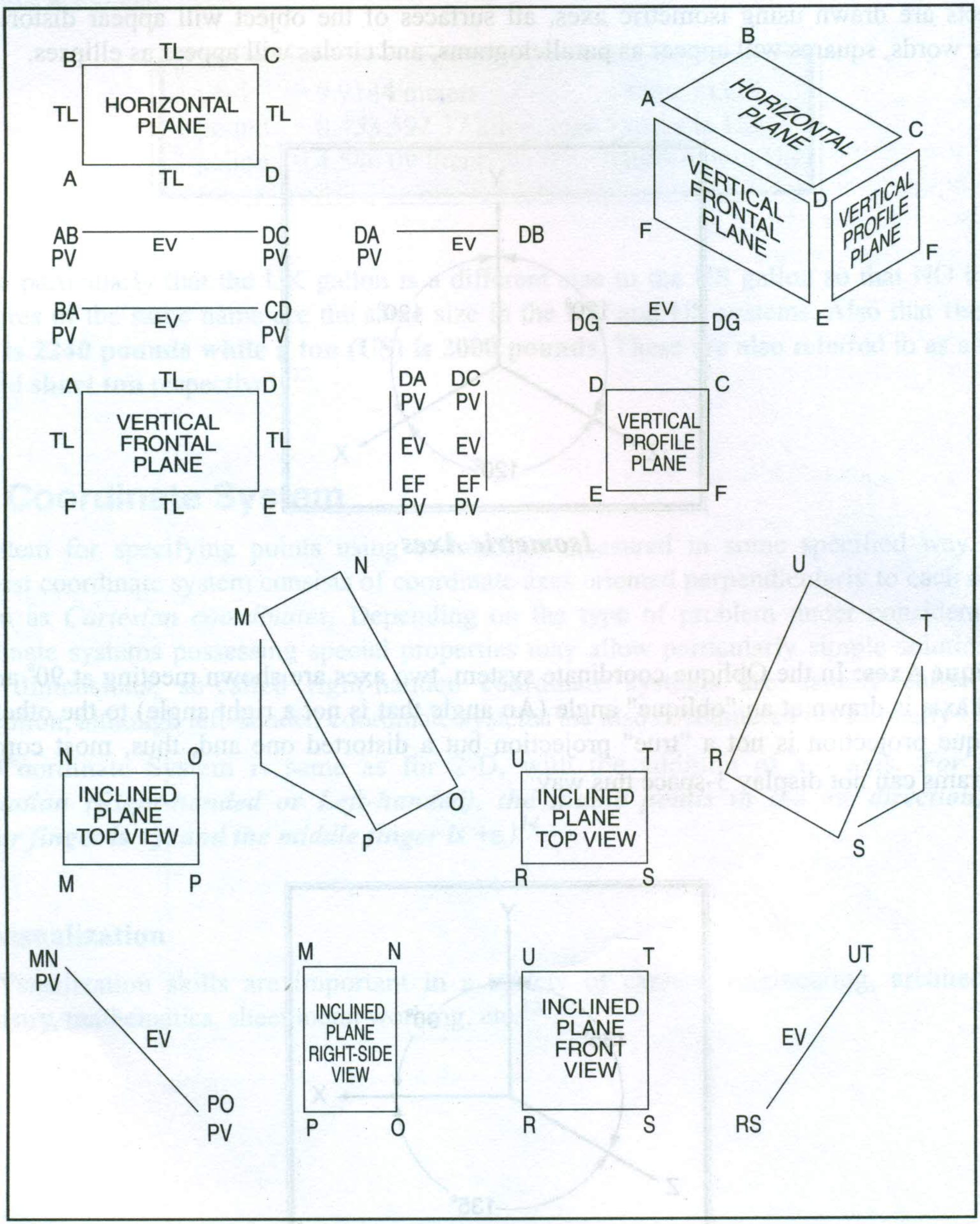
Oblique Axes: In the Oblique coordinate system, two axes are shown meeting at 90^0 and the third axis is drawn at an "oblique" angle (An angle that is not a right angle) to the other two. Oblique projection is not a "true" projection but a distorted one and, thus, most computer programs can not display 3-space this way.



Oblique Axes

Types of Planes

The Multiview and Isometric Drawings shown below illustrate four types of Planes: HORIZONTAL, FRONTAL, PROFILE and INCLINED[57].



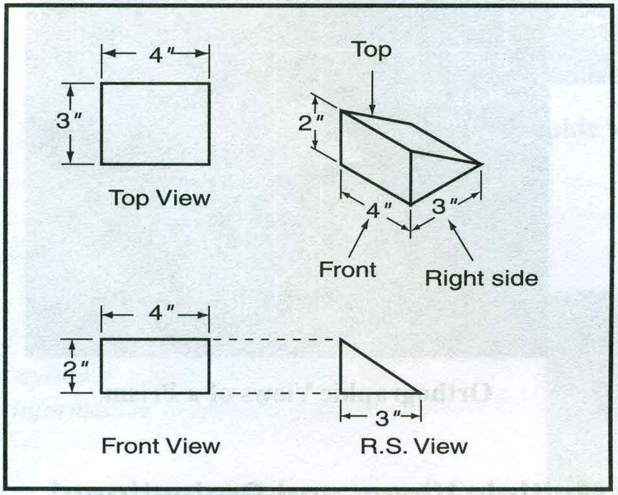
TS - True Shape
PV - Point View

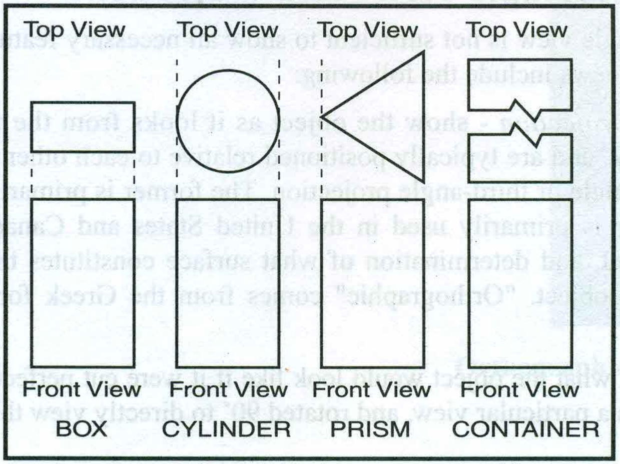
EV - Edge View
TL - True Length

which are indicated with section lines. They are used to show features not externally visible, or not clearly visible.

- *detail* - show portions of other views, "magnified" for clarity.
- *auxiliary projection* - similar to orthographic projections, however the directions of viewing are other than those for orthographic projections.
- *isometric* - show the object from angles in which the scales along each axis of the object are equal. It corresponds to rotation of the object by ± 45° about the vertical axis, followed by rotation of approximately ± 35.264° [= arcsin(tan(30°))] about the horizontal axis starting from an orthographic projection view. "Isometric" comes from the Greek for "same measure."

Exercises :





Chapter 3

Classical Viewing

3.1 Theories of Vision

Once it was assumed that we see as a result of emission of rays from the eyes. It was an Arab, who gave the first correct explanation of vision, showing that *light is reflected from an object into the eye not from eye to object.* [16]

Alhazen Abu Ali al-Hasan Ibn Al-Haitham (also: Ibn al Haythen), (965-1040), was an Arab mathematician; he is sometimes called al-Basri, after his birthplace, meaning from the city of Basra in Iraq, and sometimes called al-Misri, meaning that he came from Egypt. He is often known as Alhazen which is the Latinised version of his first name "al-Hasan". [17] He taught that vision does not result from the emission of rays from the eye, and wrote on the refraction of light, especially on atmospheric refraction, for example, the cause of morning and evening twilight. A seven volume work on optics, '*Kitab al-Manazir*', is considered by many to be ibn al-Haytham's most important contribution. It was translated into Latin as '*Opticae thesaurus Alhazeni*' in 1270. In Book I, Ibn al-Haytham makes it clear that his investigation of light will be based on experimental evidence rather than on abstract theory. He notes that light is the same irrespective of the source and gives the examples of sunlight, light from a fire, or light reflected from a mirror which are all of the same nature. *He gives the first correct explanation of vision, showing that light is reflected from an object into the eye.*

3.2 Drafting

Drafting is based on the concept of orthographic projection, which in turn is the principal concern of the branch of mathematics called *descriptive geometry*. Although preceded by the publication of related material and followed by an extensive development, the book '*Géométrie descriptive*' (1798) by Gaspard Monge, an 18th-century French mathematician, is regarded as the first exposition of descriptive geometry and the formalization of orthographic projection [18].

3.3 Descriptive Geometry

A mathematical-graphical procedure that has for its purpose the visualization of structures and their exact representation in drawings. After analysis of the structure, each element is shown in the drawing in its exact geometrical relation to the other elements.

There are two basic methods of descriptive geometry: *the projection method and the direct method.* The two methods differ as regards the attitude of mind toward the structure and toward the drawing that represents the structure [19].

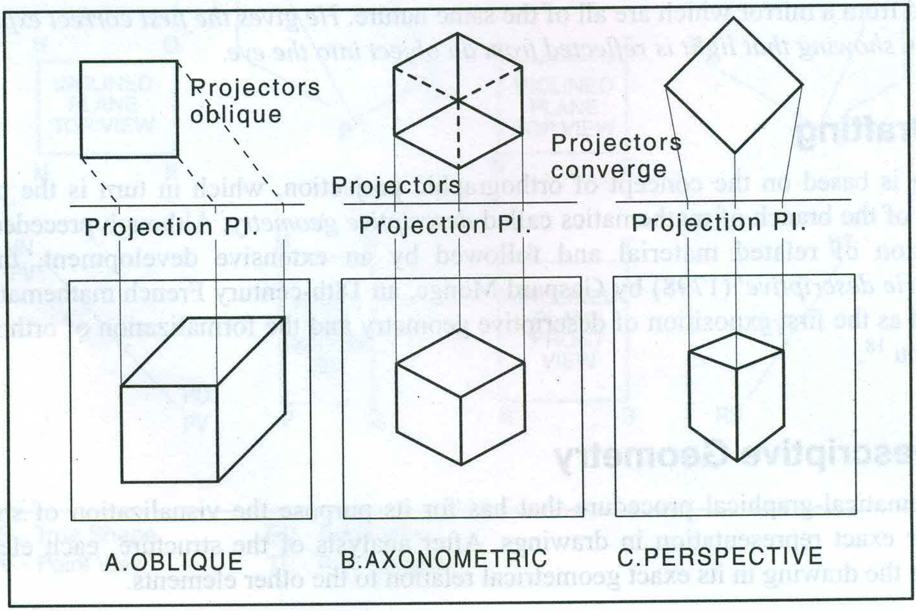
3.4 Projection Method

Gaspard Monge (1756-1818), a French mathematician [19], originated the projection method of descriptive geometry. While working as a designer for the French government, he was given the job of making plans for a proposed fortress. This was a tedious process and involved long calculations. He invented graphical solutions and completed the plans in such a short time that at first the commandant refused to accept them. For a long time the graphical process was kept a state secret, finally being revealed about 1795.

3.5 Pictorials

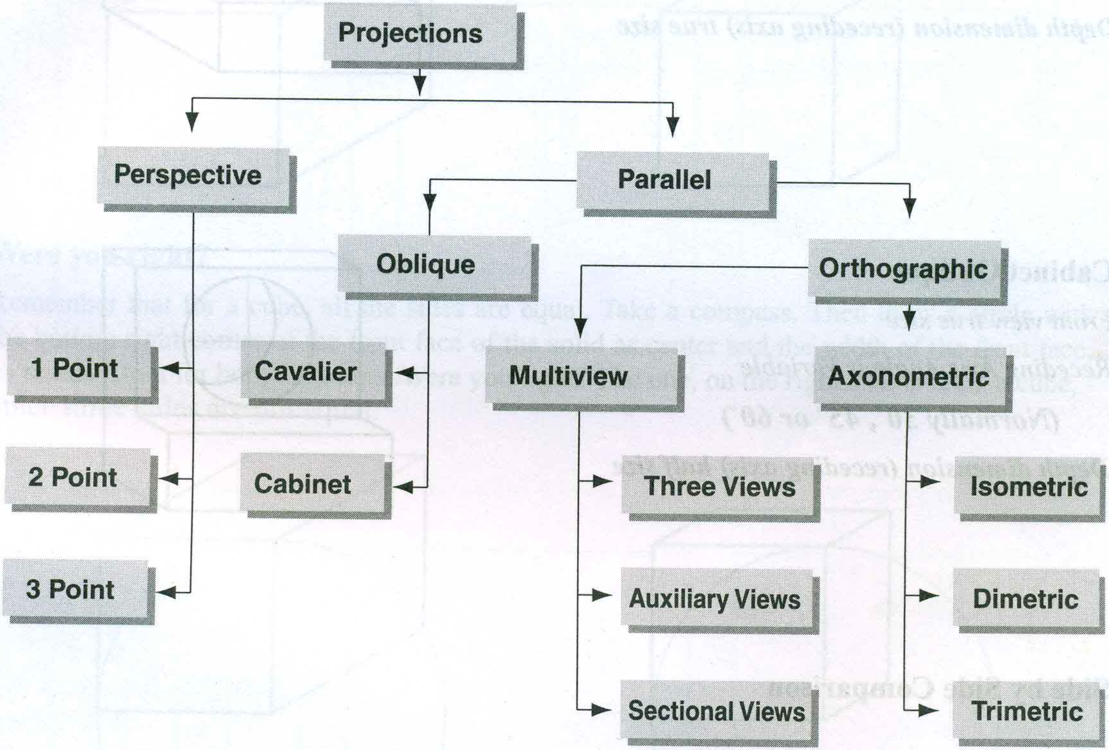
A three dimensional pictorial is a drawing that shows an object's three principal planes, much as they would be captured by a camera. Sometimes they are called Technical Illustrations [20].

- Obliques
  - *Cavalier*
  - *Cabinet*
- Axonometrics
  - *Isometrics*
  - *Dimetric*
  - *Trimetric*
- Perspectives
  - *One point*
  - *Two points*
  - *Three points*

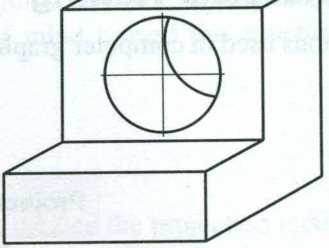


3.6 Classical Viewing

Projections used in computer graphics[21] may be classified as follows:



Cavalier Oblique



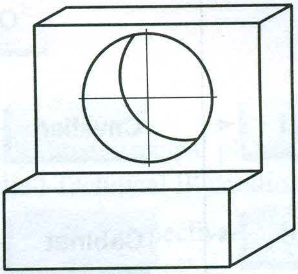
Front view true size

Receding Axis Angle is Variable

(Normally 30°, 45° or 60°)

Depth dimension (receding axis) true size

Cabinet Oblique



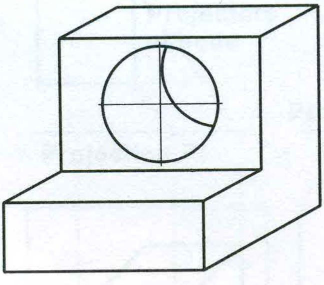
Front view true size

Receding Axis Angle is Variable

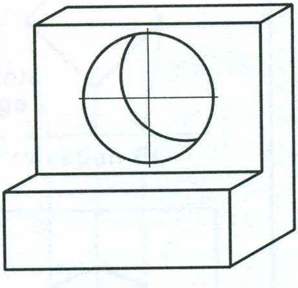
(Normally 30°, 45° or 60°)

Depth dimension (receding axis) half size

Side by Side Comparison



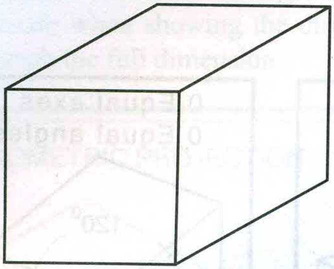
Cavalier Oblique

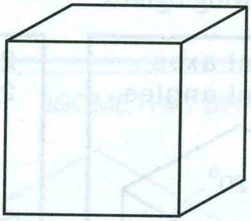


Cabinet Oblique

Which is the cube?

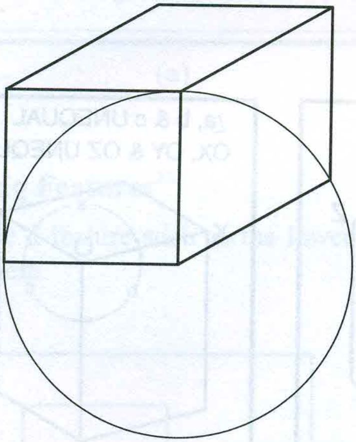
Take a quiz now! For the following two objects, which one is the cube?

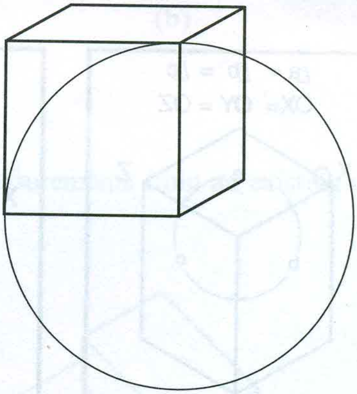




Were you right?

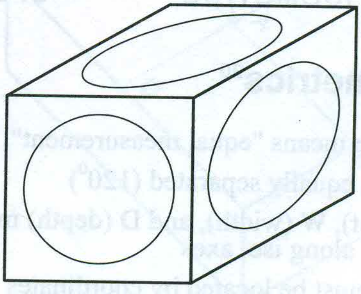
Remember that for a cube, all the sides are equal. Take a compass. Then draw a circle with the bottom right corner of the front face of the solid as center and the width of the front face, as radius. Do it for both the boxes. Were you right? The one, on the right side is NOT a cube, since three sides are not equal.





Circles in Oblique

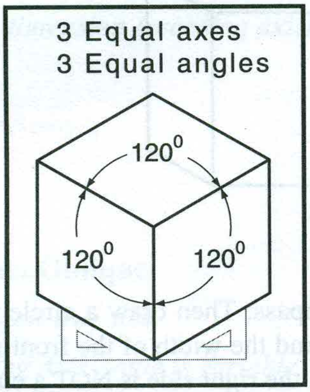
- Drawn true size in front view
- Drawn as ellipses on receding planes
- Layout using a Rhombus



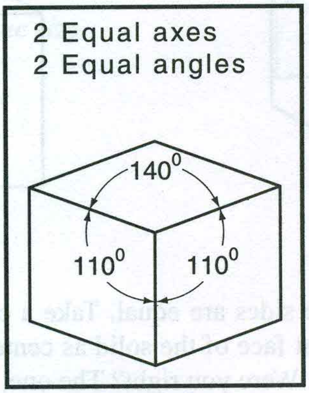
3.7 Types of Axonometrics

Axonometric projection ("to measure along axes") is a technique used in orthographic pictorials.

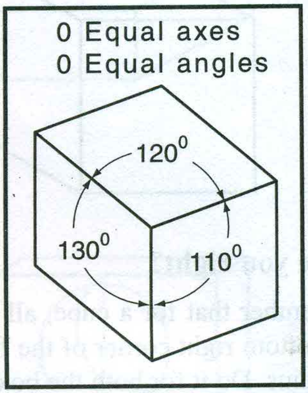
Look at the following figures[20]



A. ISOMETRIC

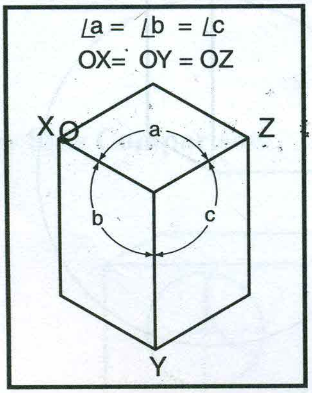


B. DIMETRIC

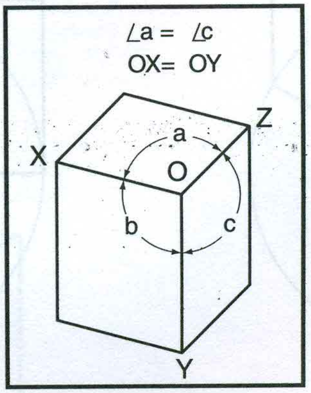


C. TRIMETRIC

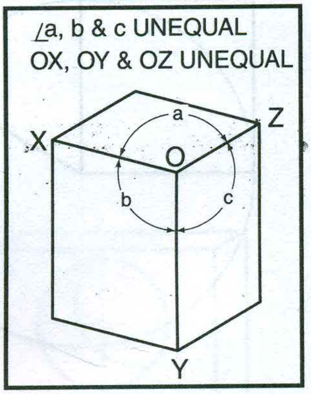
Axonometrics - more illustrations[22]



A. ISOMETRIC



B. DIMETRIC



C. TRIMETRIC

3.8 Isometrics[20]

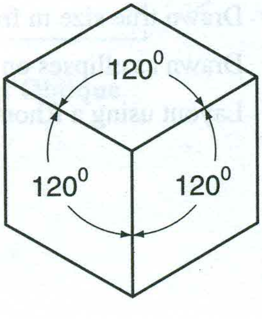
a. Isometric means "equal measurement".

b. Axes are equally separated (120^0)

c. H (height), W (width), and D (depth) measurements are true size along iso. axes

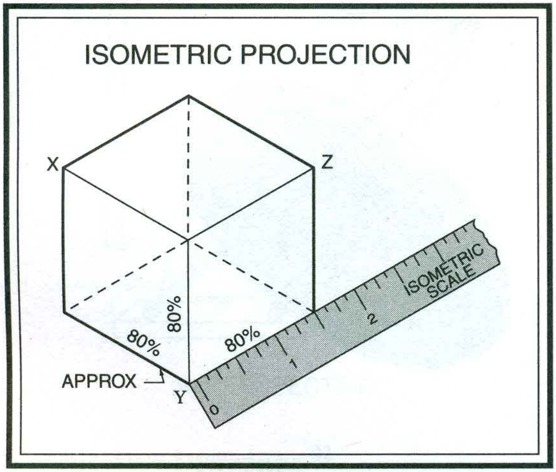
d. Angles must be located by coordinates

e. Circles appear as ellipses on all surfaces

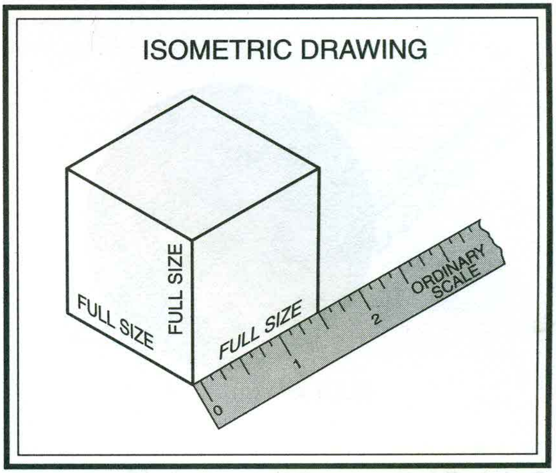


3.9 Isometric Projection vs. Sketch[22]

Isometric projections are foreshortened because the object is tipped with respect to the viewing plane. Isometric sketches are not usually foreshortened because they still appear proportionate when showing the dimensions full size along isometric axis lines. It is easier just to sketch the full dimension.



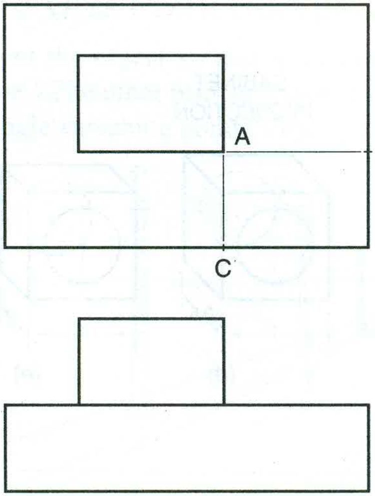
(a)

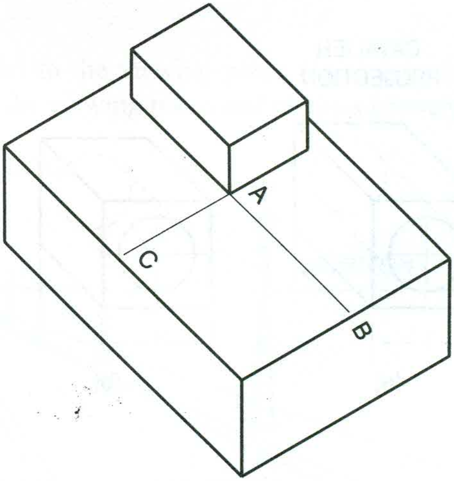


(b)

Locating Features[22]

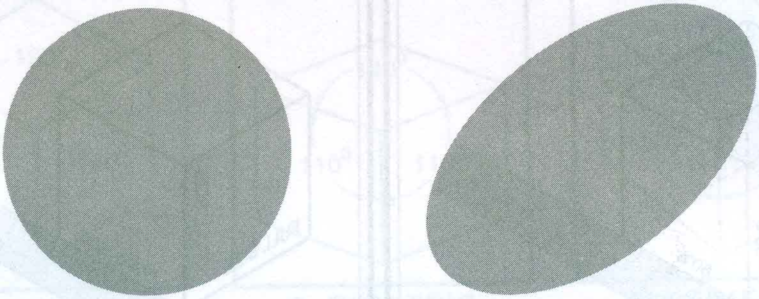
To locate a feature such as the lower block, make measurements from an existing corner as shown here.





3.10 Circles in Isometric[22]

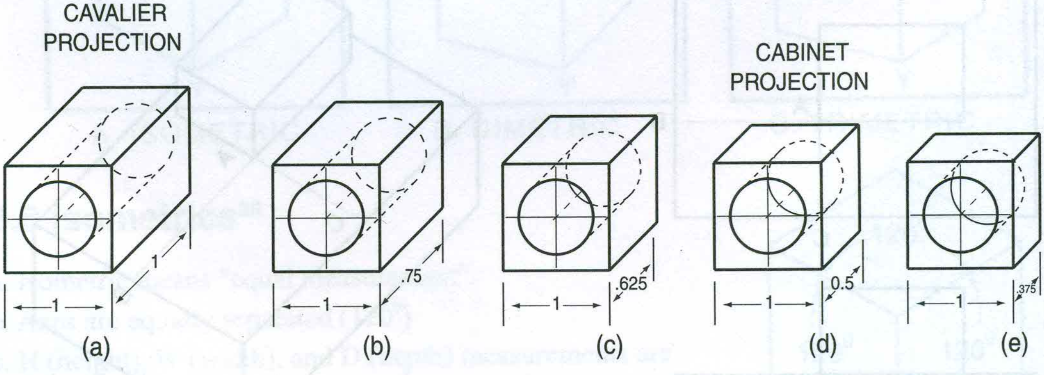
- Circles appear as ellipses when drawn in an isometric sketch.
- To sketch an isometric circle, locate the center and then sketch the box that would enclose the circular shape. Draw the ellipse tangent to the lines of the box.



3.11 Oblique Pictorials[22]

The advantage of oblique pictorials like these over isometric pictorials is that circular shapes parallel to the view are shown true shape, making them easy to sketch.

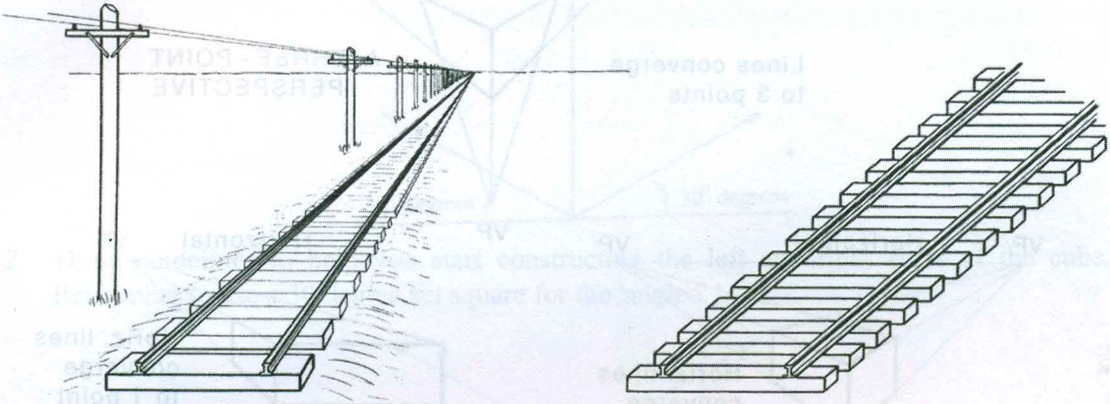
Oblique pictorials are not as realistic as isometric views because the depth can appear very distorted. Oblique views cannot usually be generated directly from a 3D model using CAD. It is primarily a sketching technique.



(a) (b) (c) (d) (e)

3.12 Unnatural Appearance of Oblique Drawing [22]

Oblique drawings of objects having a lot of depth can appear very unnatural due to the lack of foreshortening.



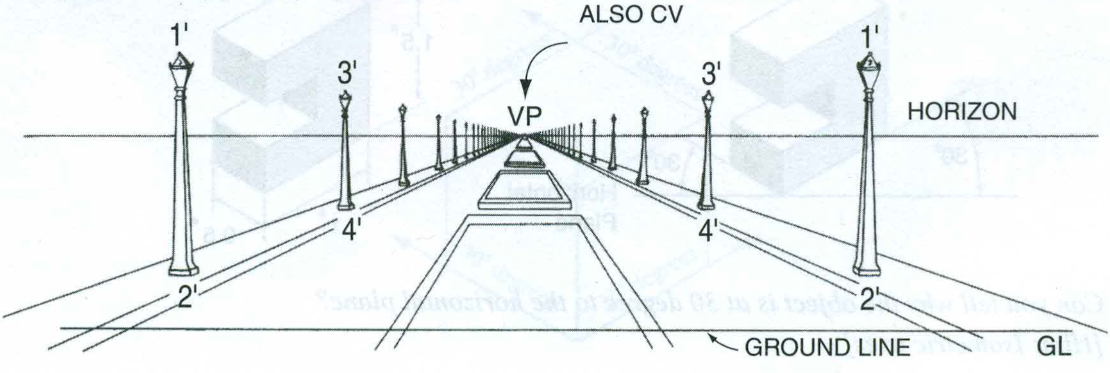
(a) PERSPECTIVE (b) OBLIQUE

Perspective Drawings [22]

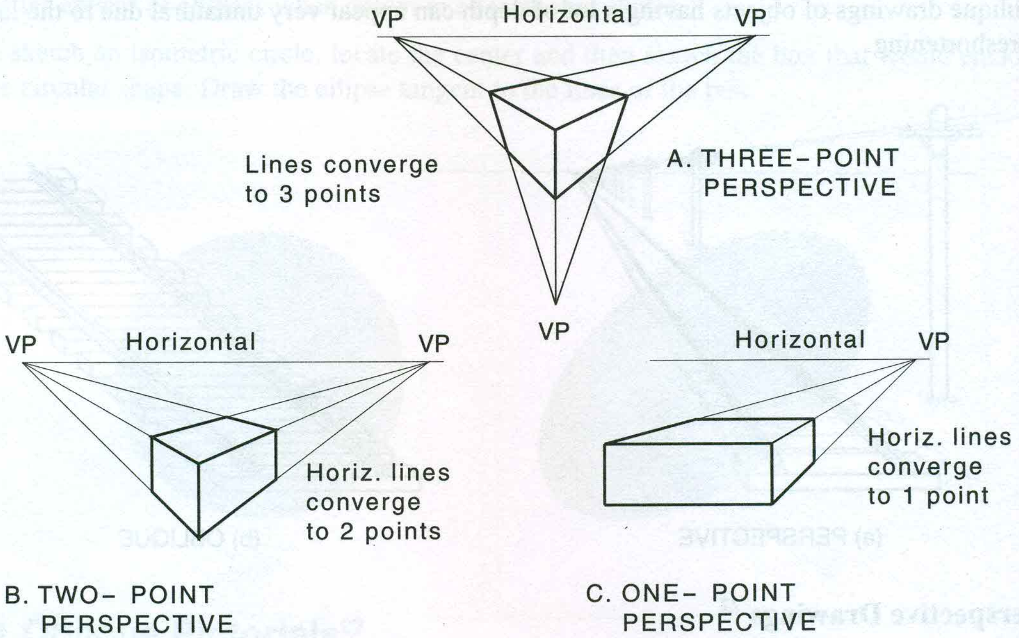
- Perspective drawings produce the view that is most realistic. A perspective drawing shows a view like a picture taken with a camera
- There are three main types of perspective drawings depending on how many vanishing points are used.
- These are called one-point, two-point, and three-point perspectives.

3.13 One Point Perspective

Orient the object so that a principal face is parallel to the viewing plane (or in the picture plane.) The other principal face is perpendicular to the viewing plane and its lines converge to a single vanishing point (VP).



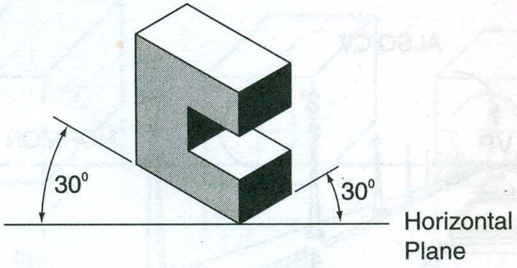
3.14 Examples of Types of Perspectives[20]

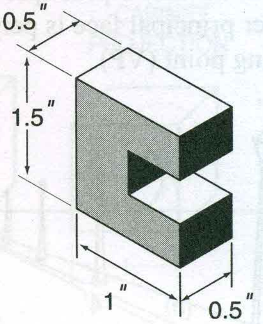

VP
Horizontal
VP
Lines converge to 3 points
A. THREE-POINT PERSPECTIVE
VP
VP
Horizontal
VP
Horiz. lines converge to 2 points
B. TWO-POINT PERSPECTIVE
Horizontal
VP
Horiz. lines converge to 1 point
C. ONE-POINT PERSPECTIVE

3.15 Drilling More on Isometric Views

Isometric means "equal measurement". The true dimension of the object is used to construct the drawing. *Because of the convenience of using actual measurements to create the isometric image, it has become the industry standard for parts manuals, technical proposals, patent illustrations and maintenance publications.*

The height of the object is measured along vertical lines. The width and depth of the object are measured along the 30 degree to the horizontal plane[23].

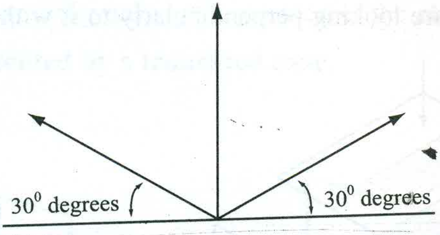




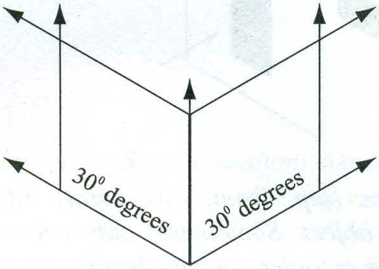
Can you tell why the object is at 30 degree to the horizontal plane?
[Hint: Isometric axes]

3.16 Isometric Projection -Simple Exercise[24]

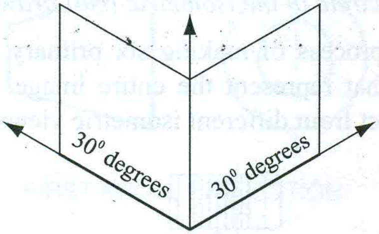
1. Draw two basic 30 degree guidelines, one to the left and one to the right, plus a vertical guideline in the centre of the drawing. In this example three edges of the cube have been drawn over the guidelines (they are slightly darker)



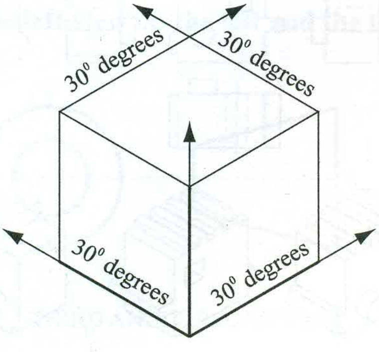
2. Draw guidelines to help you start constructing the left and right sides of the cube. Remember to use a 30 degree set square for the 'angled' lines.



3. Draw the two sides in place. They should be darker than the faint guidelines.



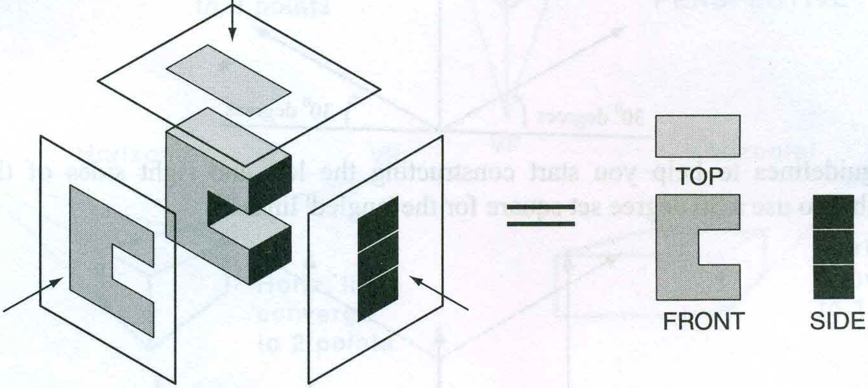
4. Complete the top of the cube by projecting lines with the 30 degree set square as shown opposite.



3.17 Orthographic Views

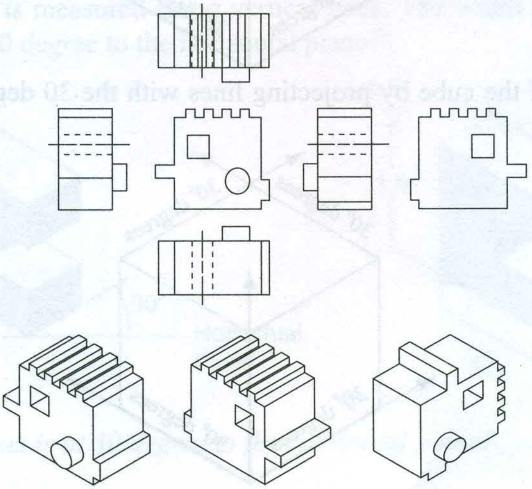
"Orthographic" comes from the Greek for "straight writing (or drawing)."[4]

Orthographic (ortho) views are two-dimensional drawings used to represent or describe a three-dimensional object. The ortho views represent the exact shape of an object seen from one side at a time as you are looking perpendicularly to it without showing any depth to the object [25].



Primarily, three ortho views (top, front, and right) adequately depict the necessary information to illustrate the object. Sometimes, only two ortho views are needed as in a cylinder. The diameter of the cylinder and its length are the only dimension information needed to complete the drawing. A sphere only needs the diameter. It is the same from all angles and remains a perfect circle in the isometric (iso) drawing.

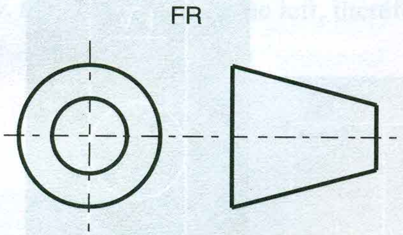
The "six" side method is a process of making six primary ortho views (i.e., ***top, bottom,, right, left, front and rear***) that represent the entire image. This method gives you all the information to create the object from different isometric views.

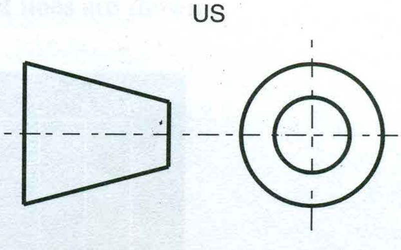


3.18 First Angle and Third Angle Orthographic Projection[4]

There are two ways to place the different views (*front, rear, top, bottom, left and right side*) on the drawing - *First Angle and Third Angle.* **The name comes from the quadrant in which the object is placed** [Try to remember the four quadrants that make up 360 degree, i.e. four 90 degree quadrants]. They differ only in the *position* of the plan, front and side views.

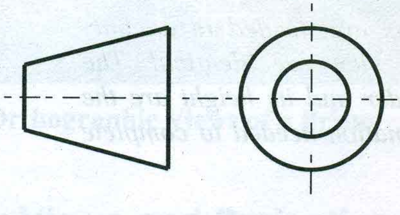
The standard in use is represented by a truncated cone.





1. ***First Angle Projection:***

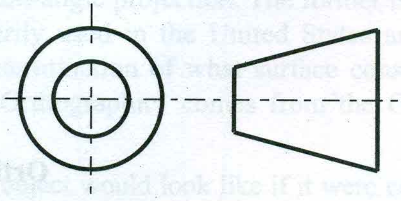
   The ISO (International Organization for Standardization) standard considers a projection on the opposite direction, like an X-ray radiography; **the top view is under the front view; the right view is at the left of the front view.** This is called First Angle Projection.



FIRST ANGLE PROJECTION

2. Third Angle Projection:

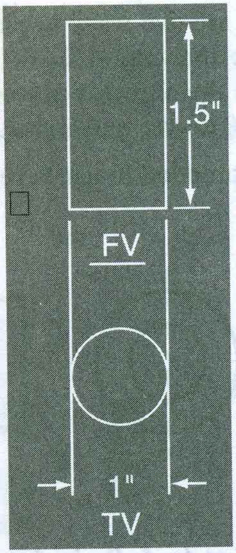
The American standard places **the left view on the left and the top view on the top.**



THIRD ANGLE PROJECTION

3.19 Simple Example with a Cylinder

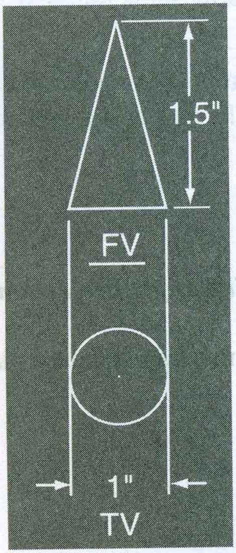
Only two ortho views are needed in a cylinder. Front view and side view are identical. The diameter of the cylinder and its length are the only dimension information needed to complete the drawing.



Orthographic Views of a Cylinder

3.20 Simple Example with a Cone

Only two ortho views are needed in a cone. Front view and side view are identical. The diameter of the cylinder and its height are the only dimension information needed to complete the drawing

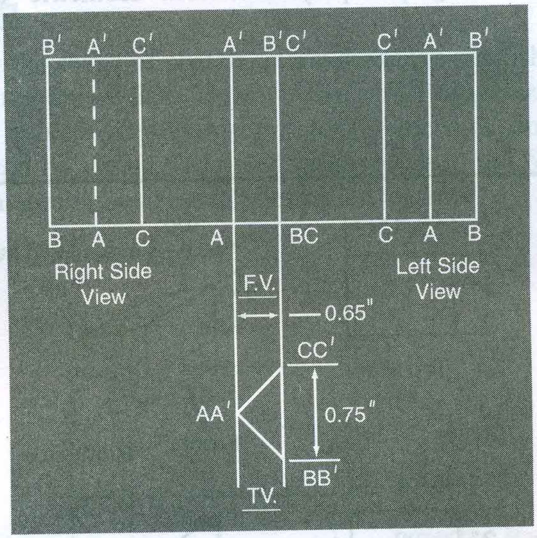


Orthographic Views of a Cone

3.21 Exercise with Prism

For the exercise with Prism, the first angle projection is used (i.e. right side view is on the left, left side view is on the right and top view is at the bottom.). Think yourself, what is the width for the F.V. and for the side views. Are they same?

Also try to get hold of the designation of the corner points (e.g. A', B' etc.). It helps to improve the understanding of the views. As you know, for the right side view, the observer is on the right, therefore the dotted lines are drawn to show the hidden line. For the left side view, the observer is on the left, therefore three distinct lines are shown.



Orthographic Views of a Prism

3.22 More on Multiple Views and Projections[4]

In most cases, a single view is not sufficient to show all necessary features, and several views are used. Types of views include the following:

- *orthographic projection* - show the object as it looks from the front, right, left, top, bottom, or back, and are typically positioned relative to each other according to the rules of either first-angle or third-angle projection. The former is primarily used in Europe and Asia, the latter is primarily used in the United States and Canada. Not all views are necessarily used, and determination of what surface constitutes the "front," etc., varies from object to object. "Orthographic" comes from the Greek for "straight writing (or drawing)."
- *section* - depict what the object would look like if it were cut perfectly along cutting plane lines defined in a particular view, and rotated 90° to directly view the resulting surface(s),

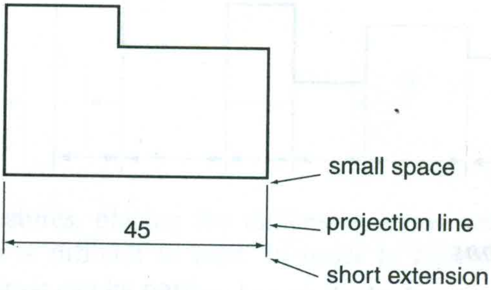
Chapter 4

Dimensioning, Line Types and Other Views

4.1 Dimensioning

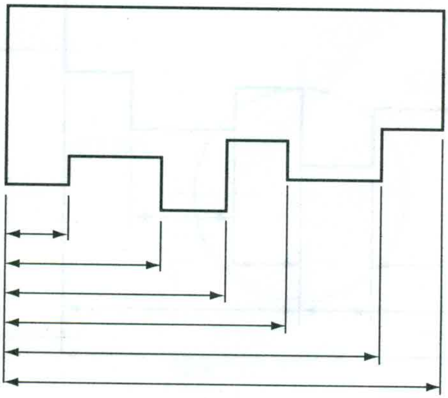
In addition to describing the shape of objects, many drawings must show dimensions, so that workers can build the structure or fabricate parts that will fit together. This is accomplished by placing the required values (measurements) along dimension lines (usually outside the outlines of the object) and by giving additional information in the form of notes which are referenced to the parts in question by angled lines called leaders[2].

An example dimension is shown below[26].

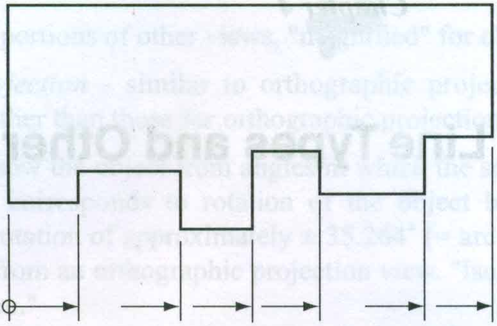


4.2 Types of Dimensioning[27]

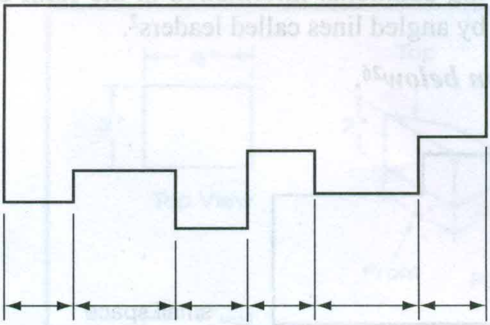
Parallel Dimensioning



Superimposed running dimension

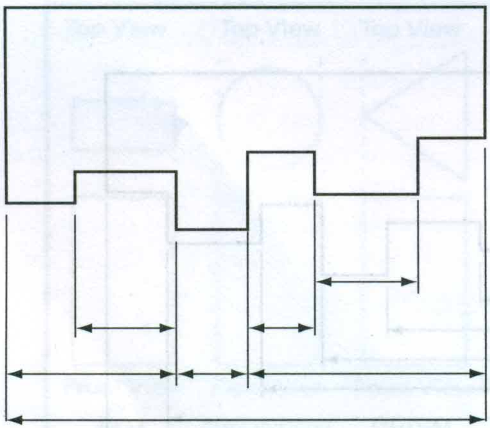


Chain Dimensioning



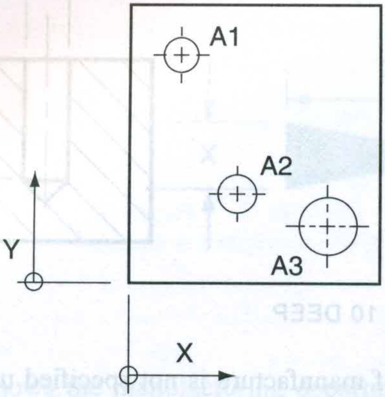
Combined Dimensions

A combined dimension uses both chain and parallel dimensioning.



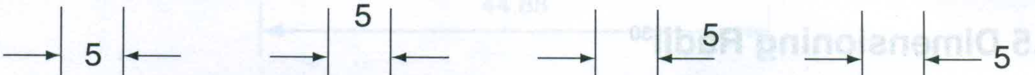
Simplified dimensioning by co-ordinates

It is also possible to simplify co-ordinate dimensions by using a table to identify features and positions.



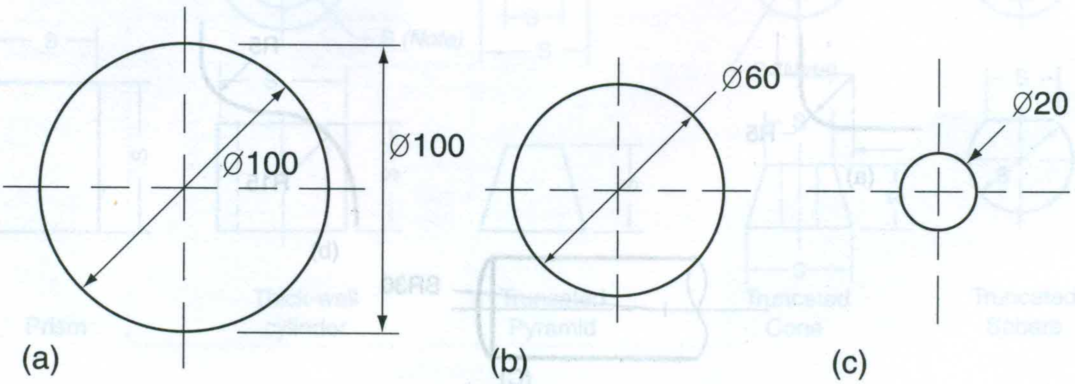
HOLE	X	Y	Q
A1	100	25	25
A2	50	40	15
A3	100	20	15

Dimensioning Small Features

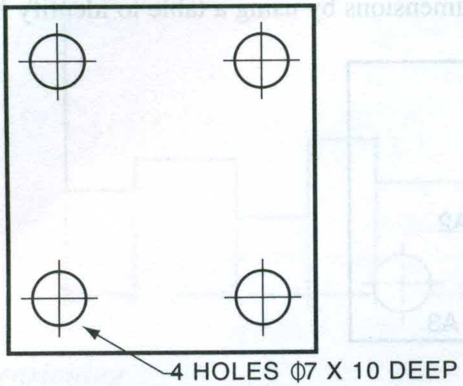


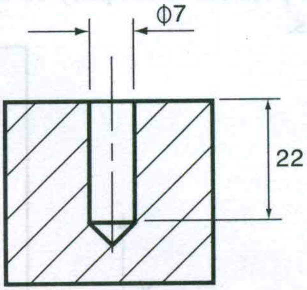
When dimensioning small features, placing the dimension arrow between projection lines may create a drawing which is difficult to read. In order to clarify dimensions on small features any of the above methods can be used.

4.3 Dimensioning Circles[28]



4.4 Dimensioning Holes[29]



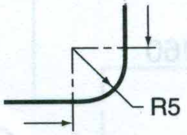


When dimensioning holes the method of manufacture is not specified unless they necessary for the function of the product. The word hole doesn't have to be added unless it is considered necessary. The depth of the hole is usually indicated if it is isn't indicated on another view. The depth of the hole refers to the depth of the cylindrical portion of the hole and not the bit of the hole caused by the tip of the drip.

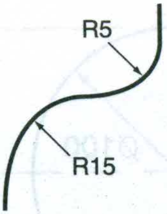
4.5 Dimensioning Radii[30]

All radial dimensions are proceeded by the capital R. All dimension arrows and lines should be drawn perpendicular to the radius so that the line passes through the centre of the arc. All dimensions should only have one arrowhead which should point to the line being dimensioned. There are two methods for dimensiong radii.

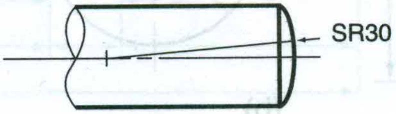
(a) shows a radious dimensioned with the centre of the radius located on the drawing.
(b) shows how to dimension radii which do not need their centers locating.
(c) Spherical dimensions: The radius of a spherical surface (i.e. the top of a drawing pin) when dimensioned should have an SR before the size to indicate the type of surface.



(a)



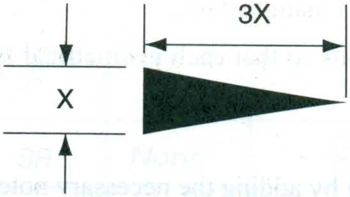
(b)



(C)

4.6 Arrowhead

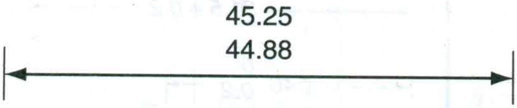
The ratio of length and width of an arrowhead should be approximately 3:1. It could be approximately 3 mm long and 1 mm wide [31].



4.7 Tolerance

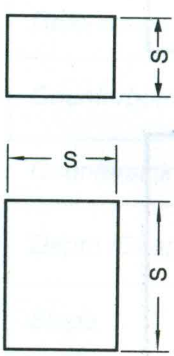
A tolerance value shows the manufacturing department the maximum permissible variation from the dimension.

The method of expressing a tolerance on a dimension as recommended by the British standards is shown below:[32]

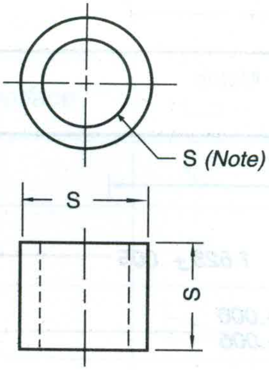


Note the larger size limit is placed above the lower limit.

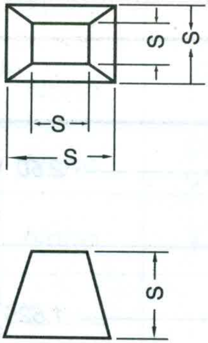
4.8 More on Dimension



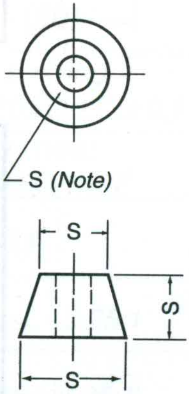
Prism



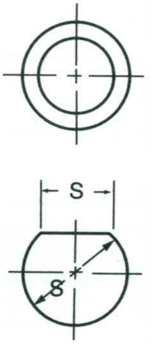
Thick-wall cylinder



Truncated Pyramid



Truncated Cone

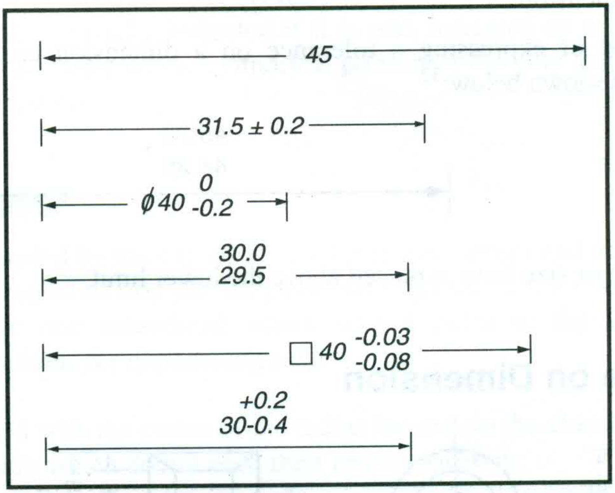


Truncated Sphere

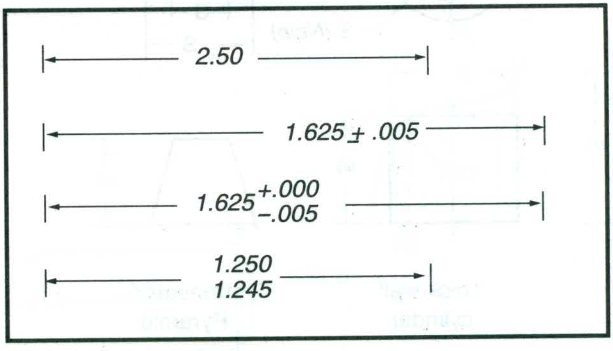
The theory of dimensioning may be applied in six steps[33], as follows:

1. Mentally divide the object into its component geometrical shapes.
2. Place the size dimensions on each form.
3. Select the locating center lines and surfaces after giving careful consideration to mating parts and to the processes of manufacture.
4. Place the location dimensions so that each geometrical form is located from a center line or finished surface.
5. Add the overall dimensions.
6. Complete the dimensioning by adding the necessary notes.

4.9 Dimension Line[34]

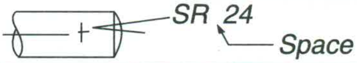
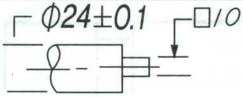
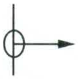
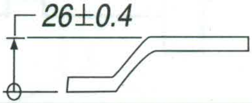


(a) Metric



(b) Decimal Inch

4.10 Drawing Symbols[35]

ANSI Y14.5M-1982 AND ISO			
SYMBOL FOR	ANSI	ISO	EXAMPLES
Radius	R	R	R1oo
Spherical Radius	SR	None	
Diameter	∅	∅	∅10±0.1
Spherical Diameter	S∅	None	S∅36$^{0}_{-0.4}$
Arc Length	⌒	None	$\overset{\frown}{40}$
Square (Shape)	□	□	
Dimension Origin		None	
Dimension Not To Scale	$\underline{18}$	$\underline{18}$	$\underline{95}$
Number of Times /Places	X	X	Space 5X ∅8
Reference Dimension	( )	None	(50)
Counterbore/Spotface	⌴	None	∅6±0.1THRU ⌴ ∅10±0.1T3±0.1
Countersink	⌵	None	∅6±0.1THRU ⌵∅10±0.1X82°
Depth /Deep	↧	None	↧3±0.1
Slope	⌳	⌳	⌳ 0.25:1
Conical Taper	⌲	⌲	⌲ 0.25:1

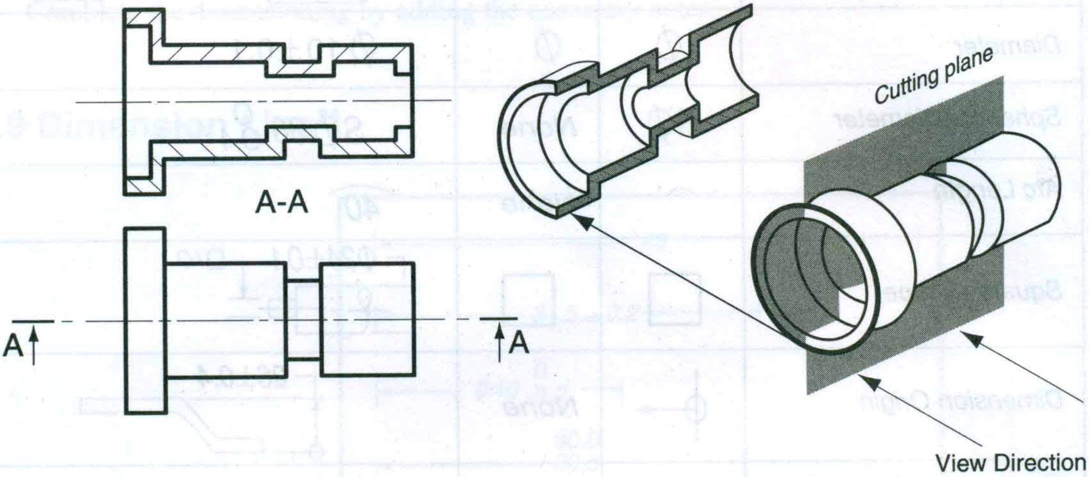
General drawing symbols.

4.11 Sectional Views[36]

Sections and sectional views are used to show hidden detail more clearly. They are created by using a cutting plane to cut the object.

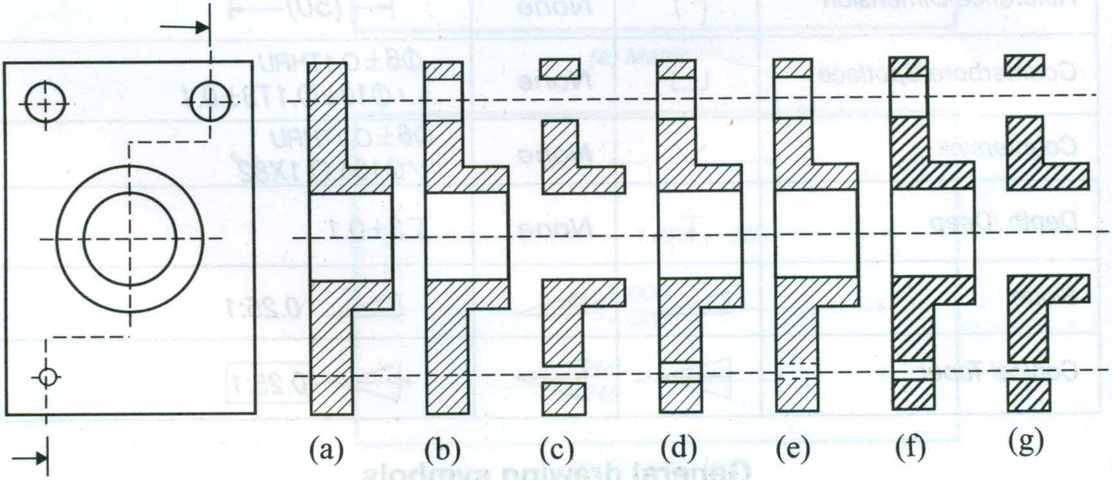
A section is a view of no thickness and shows the outline of the object at the cutting plane. Visible outlines beyond the cutting plane are not drawn.

A sectional view, displays the outline of the cutting plane and all visible outlines which can be seen beyond the cutting plane. The diagram below shows a sectional view, and how a cutting plane works.



4.12 Which Sectional View is Correct?[37]

Consider the following diagrams and find the correct sectional view.



4.13 Have You Found It?

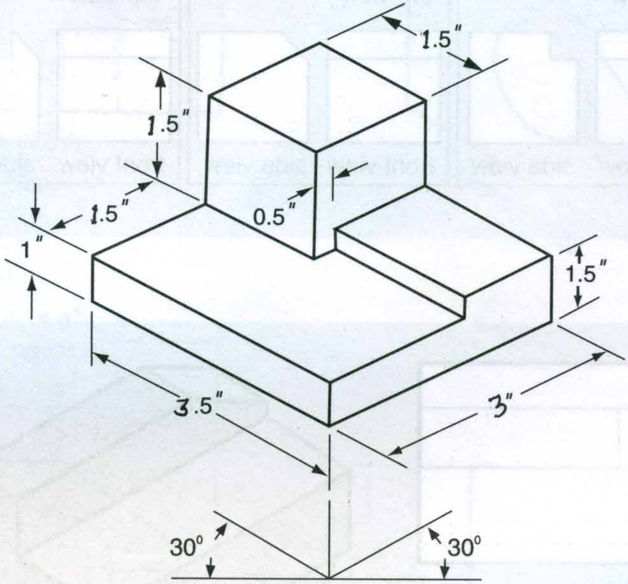
The answer may be tricky, but I wish, you try yourself as I tried myself.

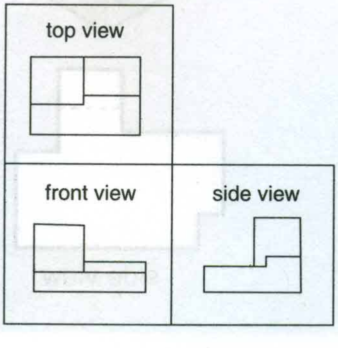
Well, may be you have the right answer. There are two figures near the answer. One in the middle (fourth from either side) and the other is the second one from right. However, the correct answer is the one in the middle not the second one from the right, since the hatching is darker. By convention, the hatching should be drawn with thin lines, lighter than the outer borders. Therefore, the one in the middle is the best choice.

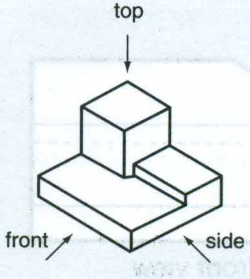
Exercises

Exercise 1:

Draw the figure with dimension. Then draw the figure with top, front and side views yourself and then check with the following. Do not cheat!

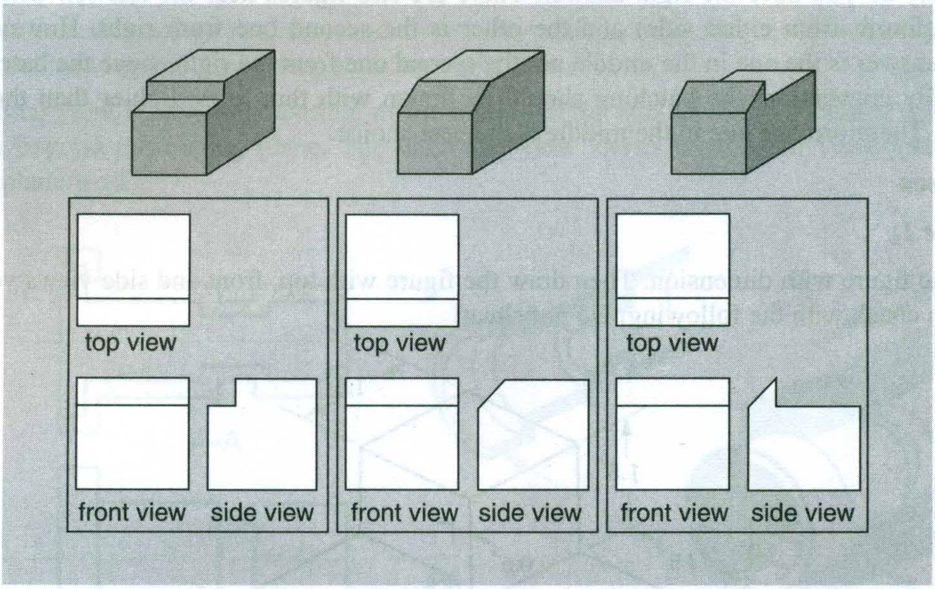


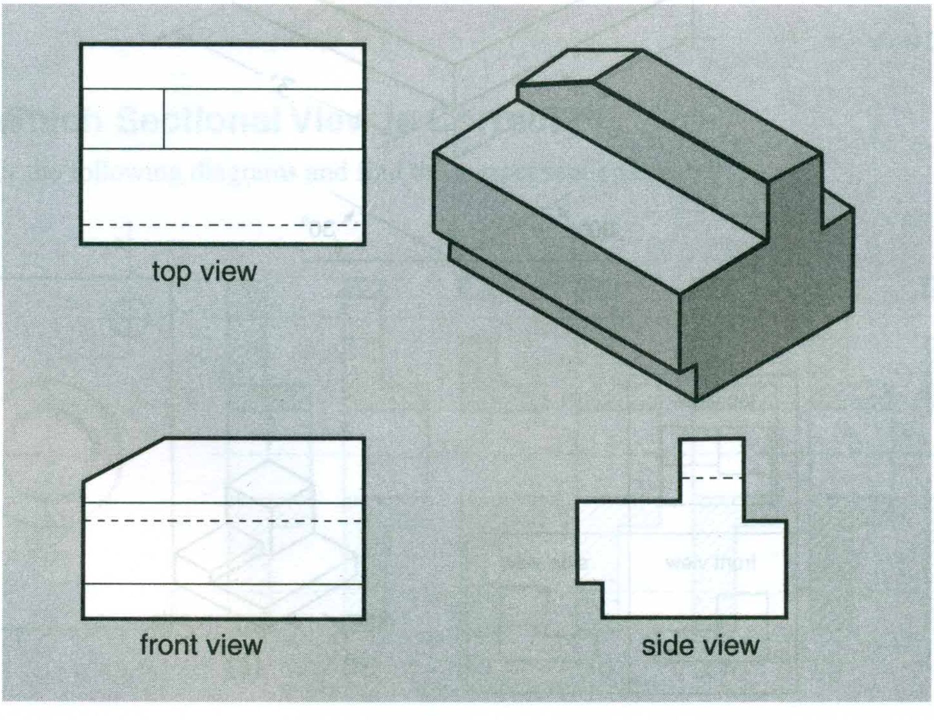




Exercise 2:

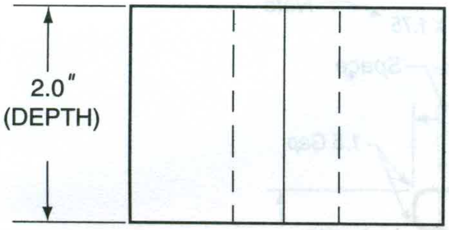
Now look at the examples below



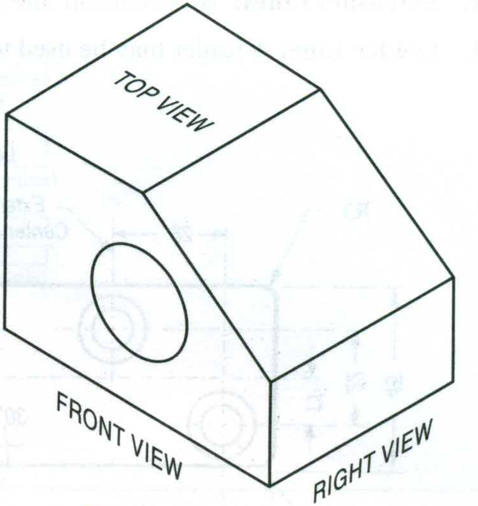


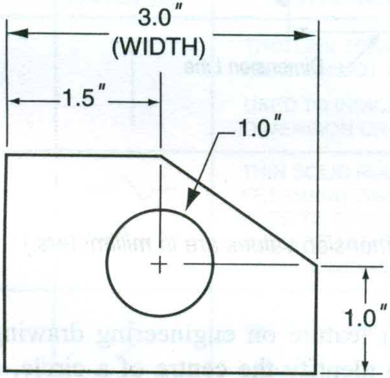
Exercise 3 :

Courtesy of Art Whitton, NV, USA

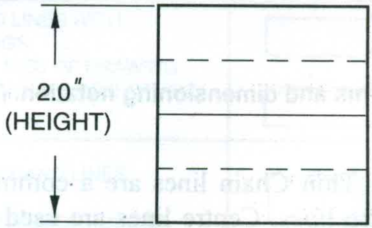


TOP VIEW





FRONT VIEW

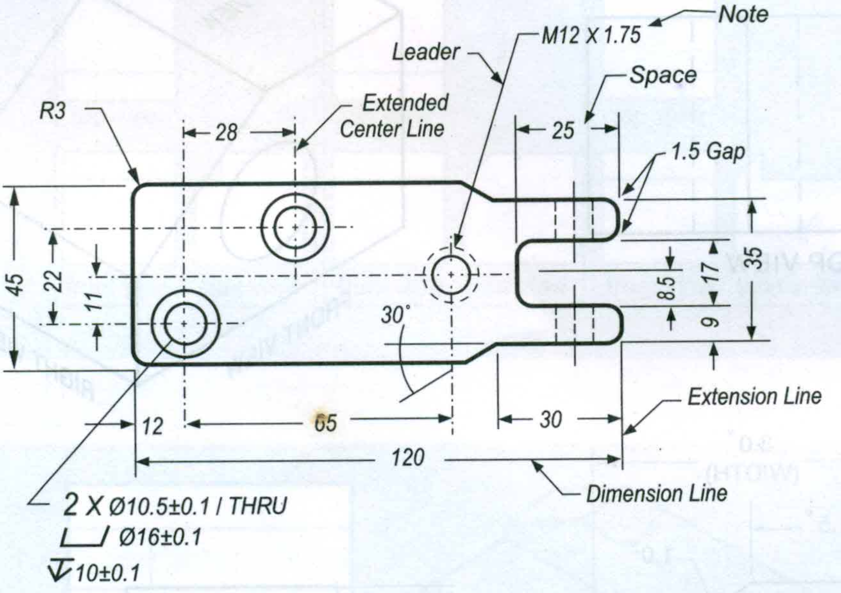


RIGHT VIEW

4.14 Various Line Types

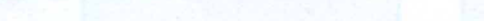
The following typical line types are described with the information available over the internet [38,39, 40, 41, 42]

1. **Dimension Line:** Line thickness is thin. It shows the dimension. It is sometimes broken in the middle to allow the placement of the dimension value, with arrowheads at each end.
2. **Extension Lines:** An extension line extends a line on the object to the dimension line.
3. **Leader Line:** A leader may be used to indicate a note or comment about a specific area

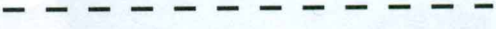


Terms and dimensioning notation. *(Dimension values are in millimeters.)*

4. **Chain lines:** Thin Chain lines are a common feature on engineering drawings used to indicate centre lines. Centre lines are used to identify the centre of a circle, cylindrical features, or a line of symmetry.

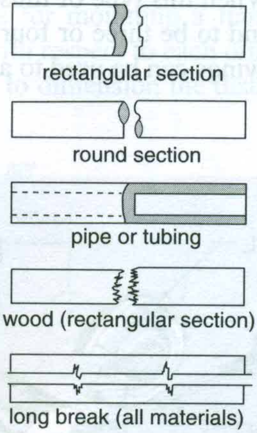


5. **Dashed lines:** Dashed lines are used to show important hidden detail for example wall thickness and holes.

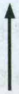
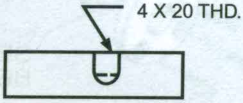
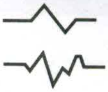
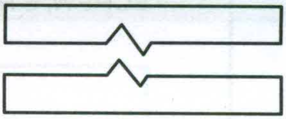
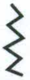
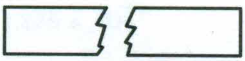
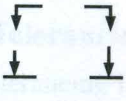
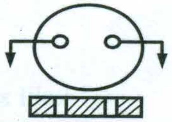
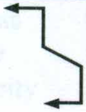
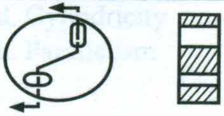


4.15 Conventional Breaks

Conventional breaks and other symbols to indicate details [43]

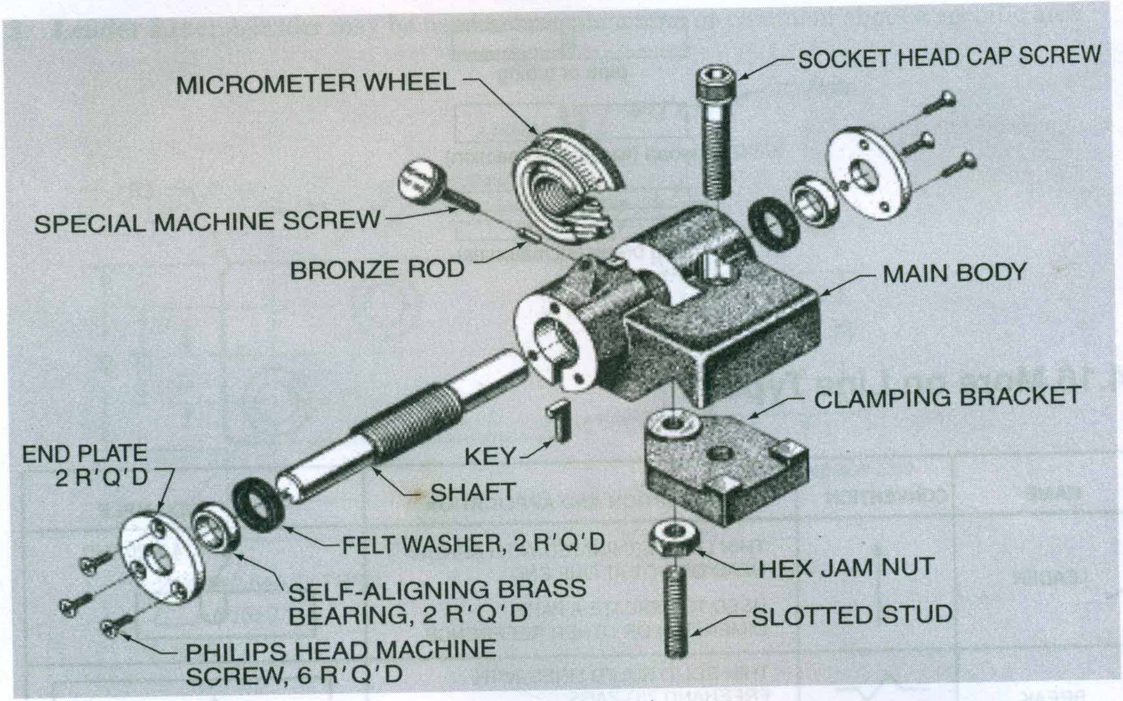


4.16 More on Line Types

NAME	CONVENTION	DESCRIPTION AND APPLICATION	EXAMPLE
LEADER		THIN LINE TERMINATED WITH ARROW HEAD OR DOT AT ONE END USED TO INDICATE A PART. DIMENSION OR OTHER REFERENCE	 4 X 20 THD.
BREAK (LONG)		THIN SOLID RULED LINES WITH FREEHAND ZIG-ZAGS USED TO REDUCE SIZE OF DRAWING REQUIRED TO DELINEATE OBJECT AND REDUCE DETAIL.	
BREAK (SHORT)		THICK SOLID FREE HAND LINES USED TO INDICATE A SHORT BREAK	
CUTTING OR VIEWING PLANE, VIEWING PLANE □ OPTIONAL		THICK SOLID LINES WITH ARROWHEAD TO INDICATE DIRECTION IN WHICH SECTION OR PLANE IS VIEWED OR TAKEN	
CUTTING PLANE FOR COMPLEX OR OFFSET VIEWS		THICK SHORT DASHES USED TO SHOW OFFSET WITH ARROW HEADS TO SHOW DIRECTION VIEWED	

4.17 Exploded-View

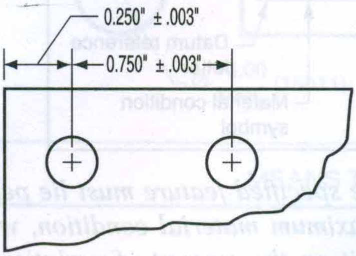
Shaded exploded-view production illustrations greatly facilitate the learning process in assembly of machines and devices. When this type of illustration is used, the initial assembly of parts into a machine has been found to be three or four times faster than if a conventional assembly drawing is used. Photo drawings can be used to achieve the same visual results [43].



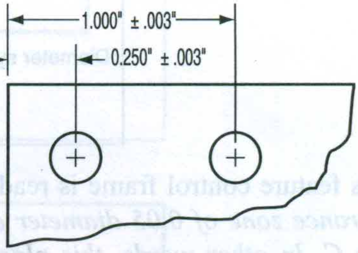
4.18 A Dimensioning Example

Showing that placement should match intent

These drawings show bolts holes for mounting a flange onto a plate. When mounting the flange, the position of the holes with respect to each other is very important, or else the flange (or part) won't fit. It makes sense to dimension the distance between the holes, instead of the distances to the edge.[52]



Dimension placement
matches intent



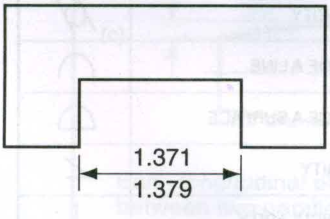
Dimension placement
does NOT match intent

4.19 Tolerances

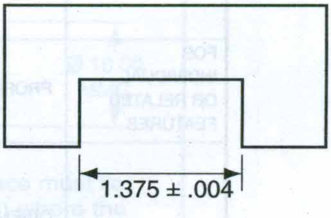
There are two types of tolerances:[52]

a. Geometric Tolerances

b. Dimensional Tolerances —— Limit Dimensioning
  Plus & Minus Tolerancing



Limit Dimensioning



Plus & Minus Tolerancing

Geometric Tolerancing

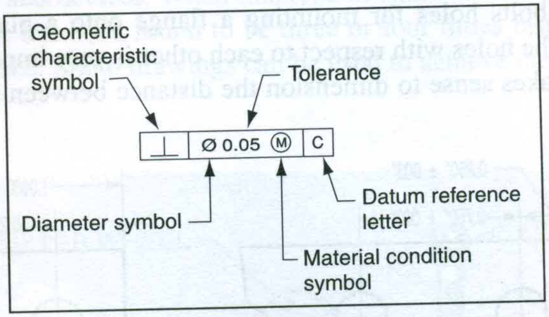
Geometric Tolerancing is used to specify the shape of features. Things like:

a. Straightness b. Flatness c. Circularity d. Cylindricity
e. Angularity f. Profiles g. Perpendicularity h. Parallelism
i. Concentricity And More...

Geometric Tolerances are shown on a drawing with a feature control frame.

4.20 The Feature Control Frame

A feature control frame gives information about geometric tolerances on the feature.



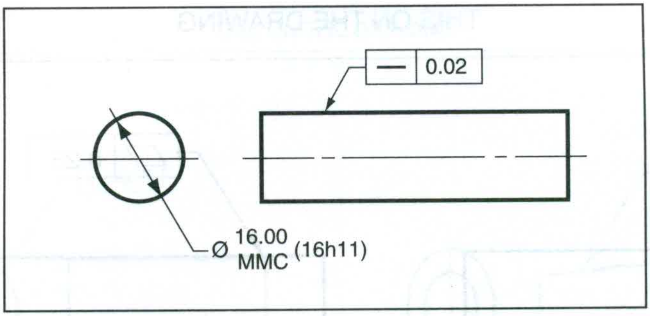
This feature control frame is read as: *"The specified feature must lie perpendicular within a tolerance zone of 0.05 diameter at the maximum material condition, with respect to datum axis C. In other words, this places a limit on the amount of variation in perpendicularity between the feature axis and the datum axis. In a drawing, this feature control frame would accompany dimensional tolerances that control the feature size and position.*

Geometric Characteristic Symbols

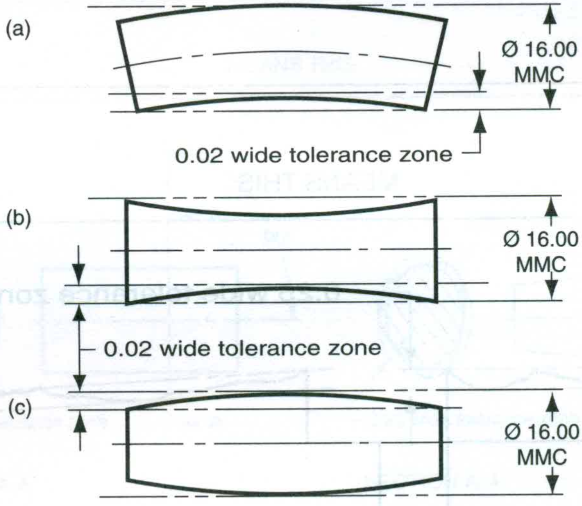
	TYPE OF TOLERANCE	CHARACTERISTIC	SYMBOL
FOR INDIVIDUAL FEATURES	FORM	STRAIGHTNESS	—
		FLATNESS	▱
		CIRCULARITY (ROUNDNESS)	○
		CYLINDRICITY	⌭
FOR INDIVIDUAL OR RELATED FEATURES	PROFILE	PROFILE OF A LINE	⌒
		PROFILE OF A SURFACE	⌓
FOR RELATED FEATURES	ORIENTATION	ANGULARITY	∠
		PERPENDICULARITY	⊥
		PARALLELISM	//
	LOCATION	POSITION	⌖
		CONCENTRICITY	◎
		SYMMETRY	⌯
	RUNOUT	CIRCULAR RUNOUT	↗
		TOTAL RUNOUT	⌰

Straightness Example

THIS ON THE DRAWING



MEANS THIS

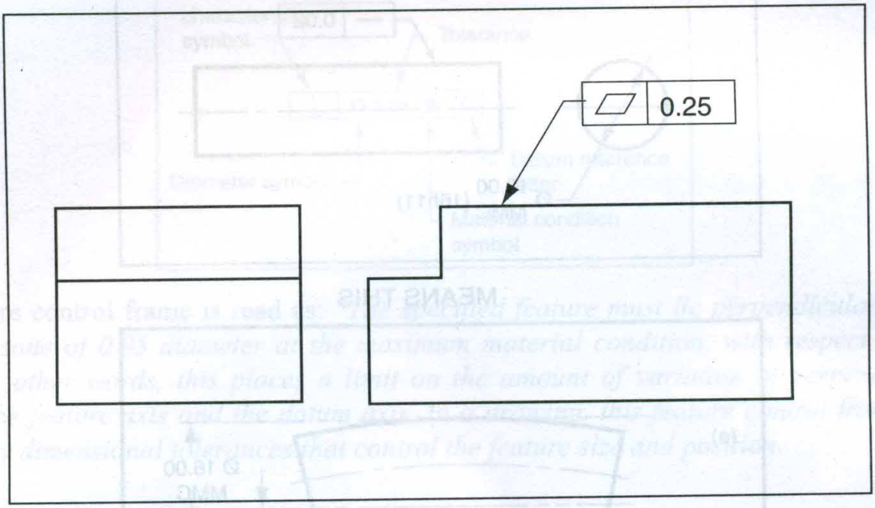


Each longitudinal element of the surface must lie between two parallel lines (0.02 apart) where the two lines and the nominal axis of the part share a common plane. The feature must be within the specified limits of size and the boundary of perfect form at MMC (16.00)

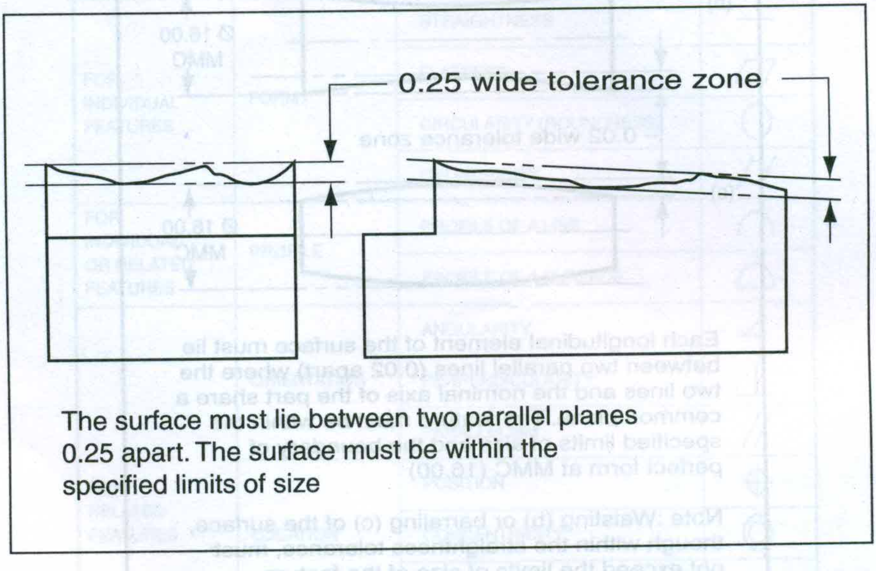
Note :Waisting (b) or barreling (c) of the surface, though within the straightness tolerance, must not exceed the limits of size of the feature.

Flatness Examples

THIS ON THE DRAWING



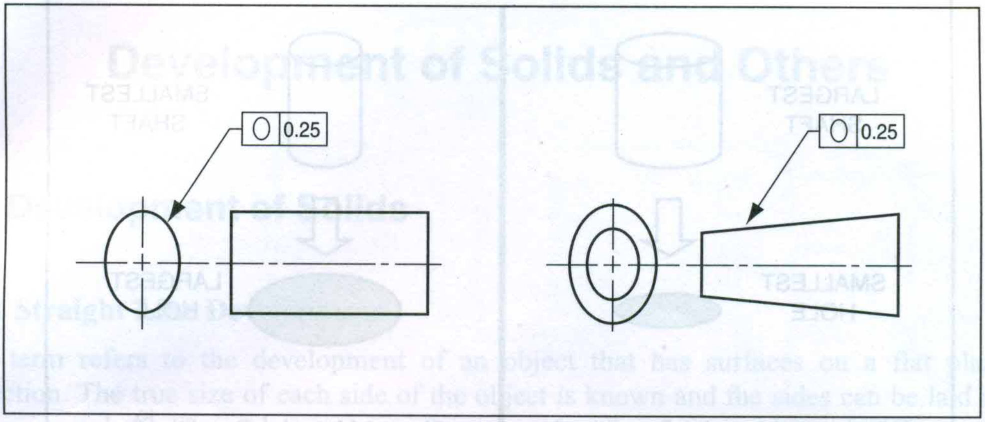
MEANS THIS



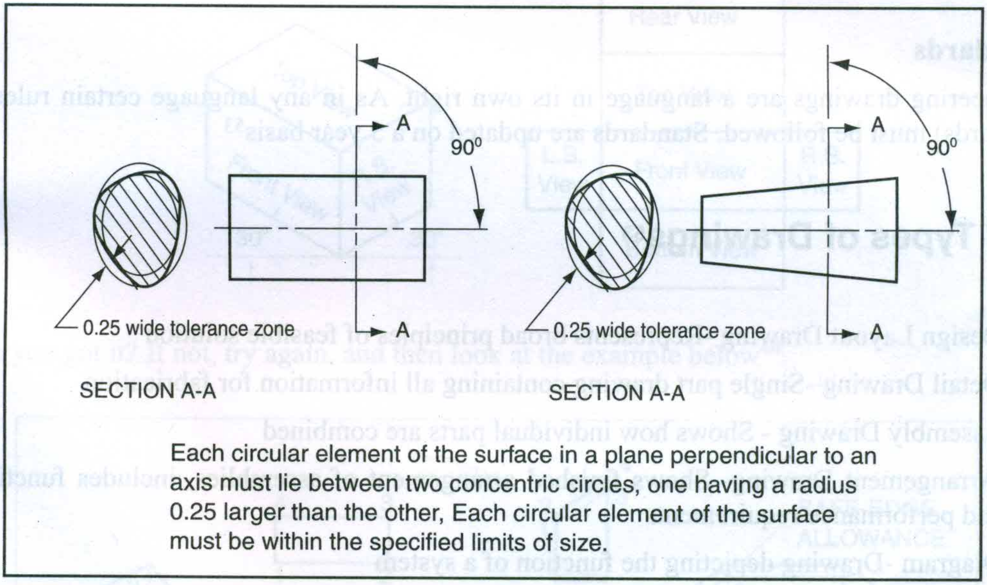
The surface must lie between two parallel planes 0.25 apart. The surface must be within the specified limits of size

Circularity (Roundness) Example

THIS ON THE DRAWING



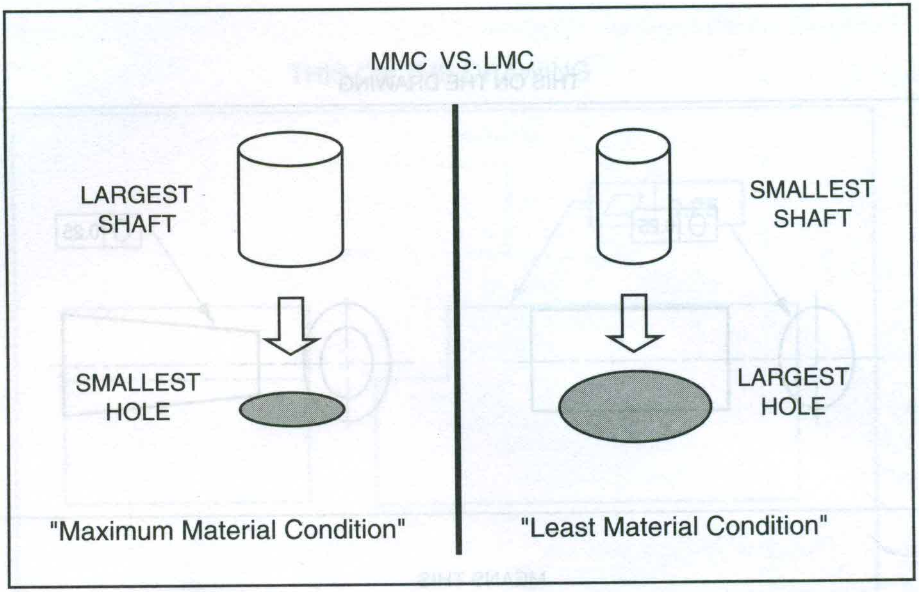
MEANS THIS



Each circular element of the surface in a plane perpendicular to an axis must lie between two concentric circles, one having a radius 0.25 larger than the other, Each circular element of the surface must be within the specified limits of size.

Circular & Total Runout

Runout is specified on cylindrical parts. It is measured by placing a gage on the part, and rotating the part through 360 degrees. The total variation is recorded as the runout. Circular runout is measured at one location. Total Runout is measured along the entire specified surface.



Standards

Engineering drawings are a language in its own right. As in any language certain rules (or standards) must be followed. Standards are updated on a 5 year basis[53]

4.21 Types of Drawings[53]

a. Design Layout Drawing -Represents broad principles of feasible solution

b. Detail Drawing -Single part drawing containing all information for fabrication

c. Assembly Drawing - Shows how individual parts are combined

d. Arrangement Drawing- Shows finished arrangement of assemblies, includes functional and performance requirements

e. Diagram -Drawing depicting the function of a system

Chapter 5

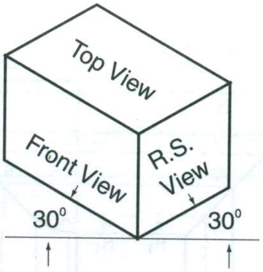
Development of Solids and Others

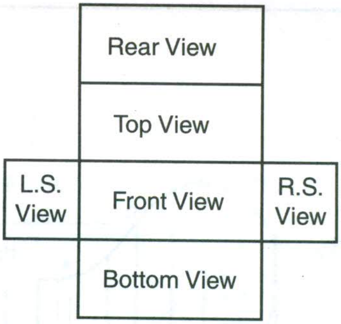
5.1 Development of Solids

5.1.1 Straight Line Development

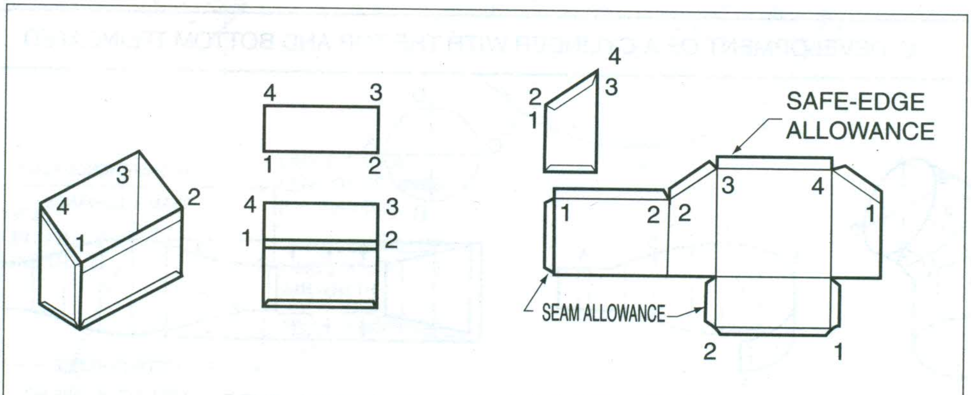
This term refers to the development of an object that has surfaces on a flat plane of projection. The true size of each side of the object is known and the sides can be laid out in successive order[44].

Now look at the simple example[45]





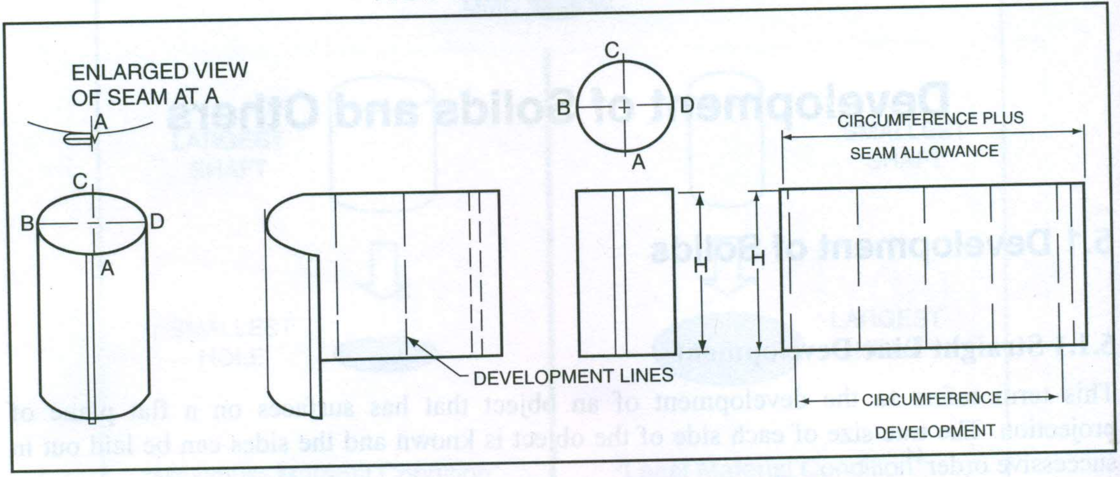
Have you got it? If not, try again, and then look at the example below[44].



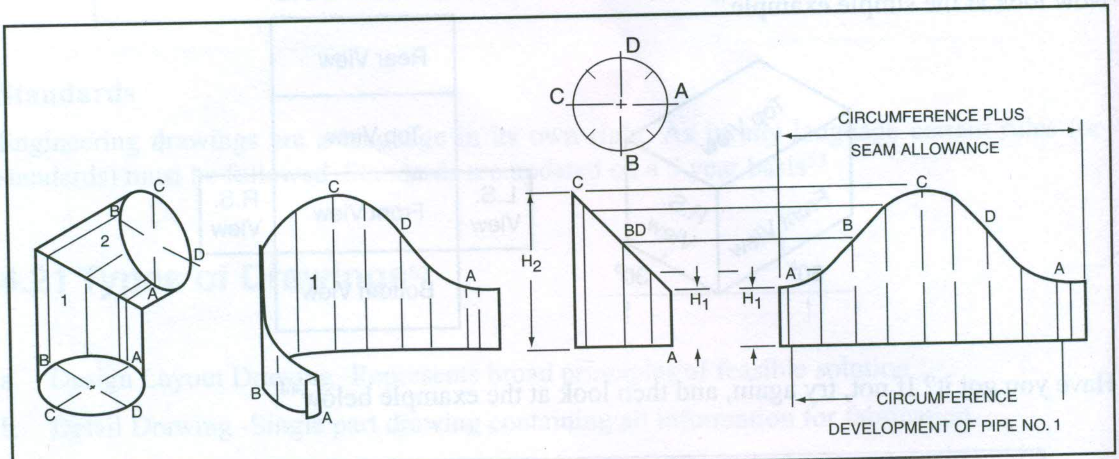
DEVELOPMENT (OUTSIDE SURFACE SHOWN)

5.1.2 Parallel Line Development[46]

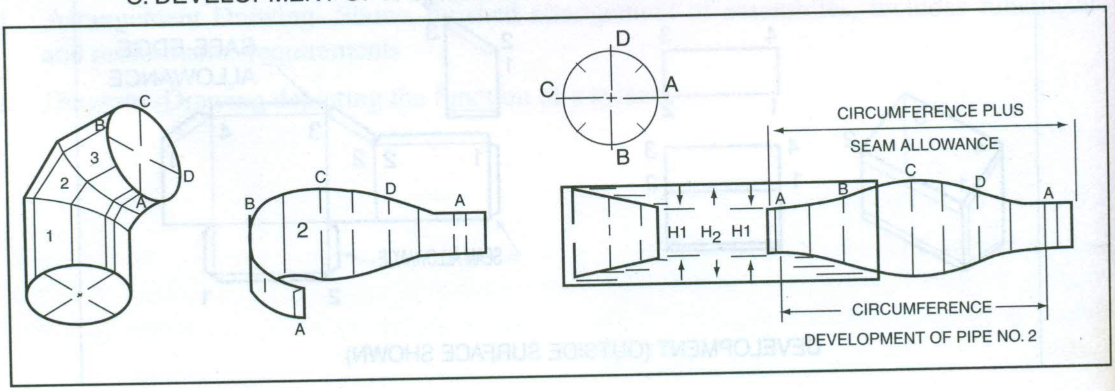
A. DEVELOPMENT OF A CYLINDER



B. DEVELOPMENT OF A TRUNCATED CYLINDER

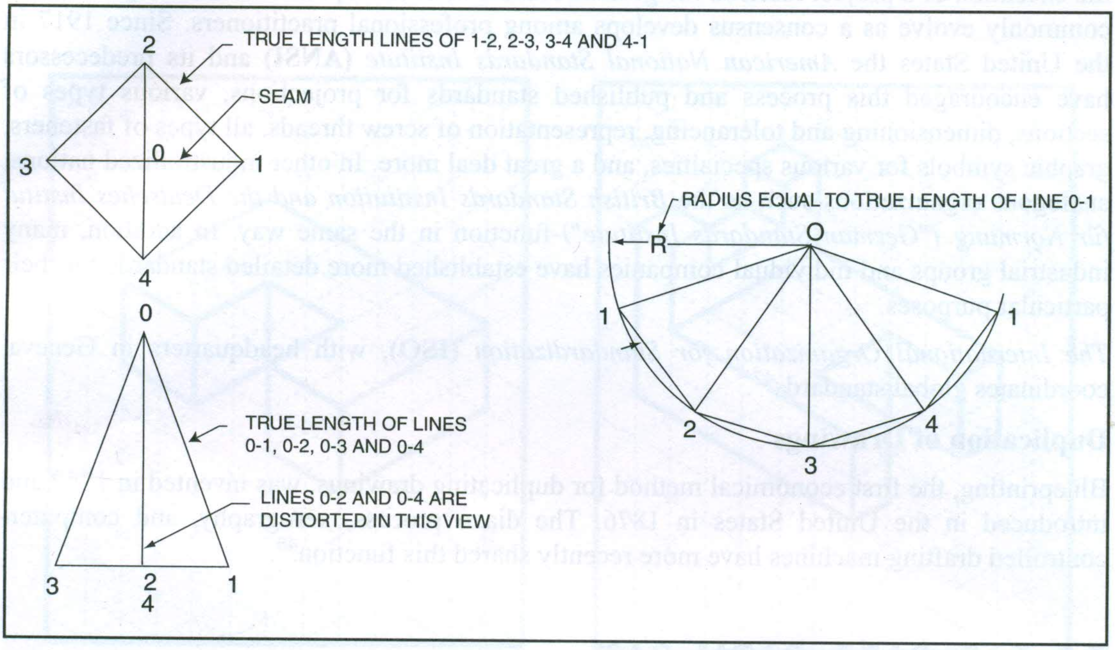


C. DEVELOPMENT OF A CYLINDER WITH THE TOP AND BOTTOM TRUNCATED

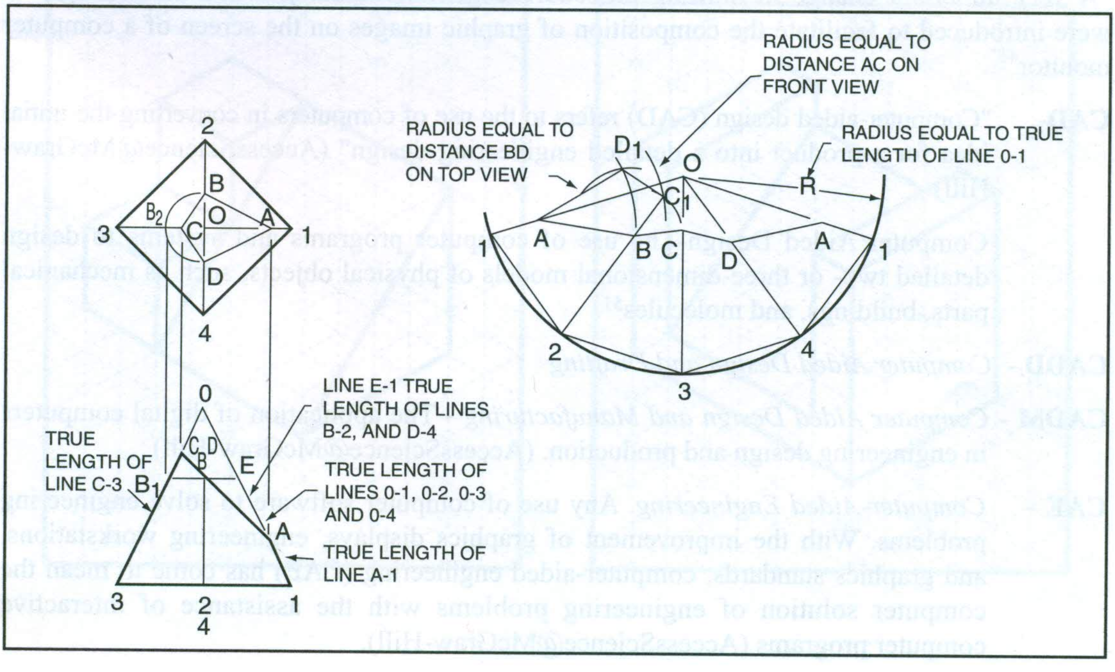


5.1.3 Radial-Line Development

A. DEVELOPMENT OF A PYAMID



B. DEVELOPMENT OF A TRUNCATED PYRAMID



5.2 Drafting Practice - Standards

The value of a set of drawings conveying the complete and correct information necessary for the execution of a project fostered the gradual standardization of practices. Drafting standards commonly evolve as a consensus develops among professional practitioners. Since 1917 in the United States the *American National Standards Institute* **(ANSI)** and its predecessors have encouraged this process and published standards for projections, various types of sections, dimensioning and tolerancing, representation of screw threads, all types of fasteners, graphic symbols for various specialties, and a great deal more. In other industrialized nations, analogous organizations-such as the *British Standards Institution and the Deutsches Institut für Normung ("German Standards Institute")*-function in the same way. In addition, many industrial groups and individual companies have established more detailed standards for their particular purposes.

The International Organization for Standardization **(ISO)**, with headquarters in Geneva, coordinates global standards[47].

Duplication of Drawings

Blueprinting, the first economical method for duplicating drawings, was invented in 1842 and introduced in the United States in 1876. The diazo process, xerography, and computer-controlled drafting machines have more recently shared this function[48].

5.3 CAD, CADD, CADM, CAE

"A very important change in drafting procedure began in the early 1960s when programs were introduced to facilitate the composition of graphic images on the screen of a computer monitor[48]"

CAD- "Computer-aided design (CAD) refers to the use of computers in converting the initial idea for a product into a detailed engineering design" (AccessScience@McGraw-Hill)

Computer Aided Design-The use of computer programs and systems to design detailed two- or three-dimensional models of physical objects, such as mechanical parts, buildings, and molecules[51].

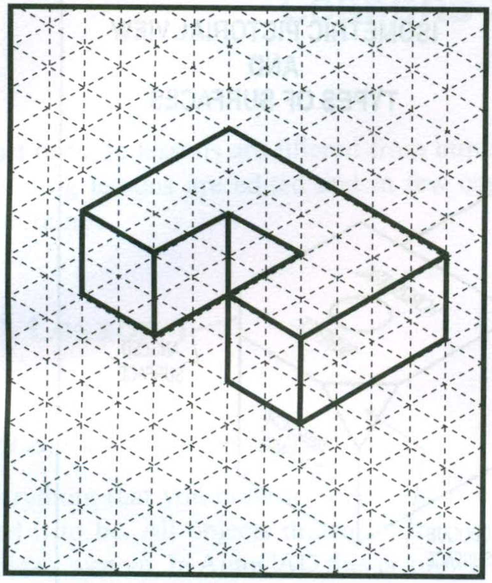
CADD - *Computer Aided Design and Drafting*

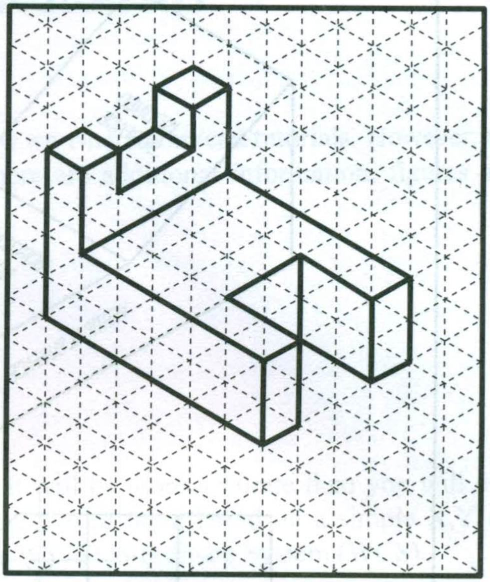
CADM - *Computer Aided Design and Manufacturing* - The application of digital computers in engineering design and production. (AccessScience@McGraw-Hill)

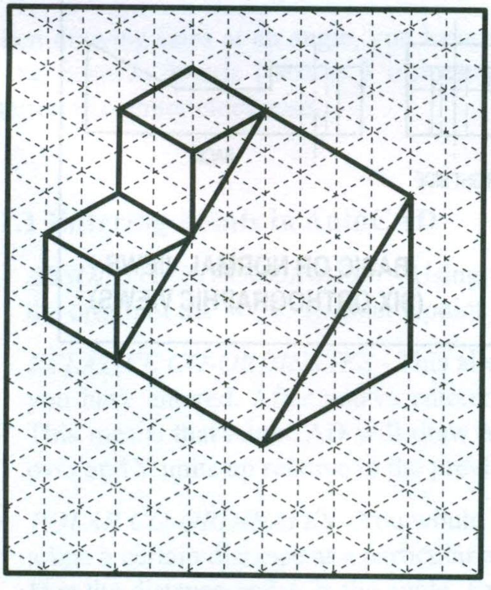
CAE - *Computer-Aided Engineering.* Any use of computer software to solve engineering problems. With the improvement of graphics displays, engineering workstations, and graphics standards, computer-aided engineering (CAE) has come to mean the computer solution of engineering problems with the assistance of interactive computer programs (AccessScience@McGraw-Hill).

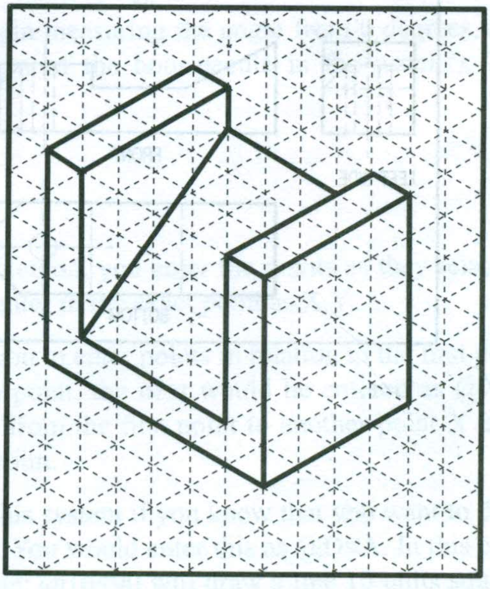
Exercises :

Put arrow in whatever direction you want and assume it as front side and then draw front, right side and top views. Figures are courtesy of Mr. Aaron Phoenix[49]

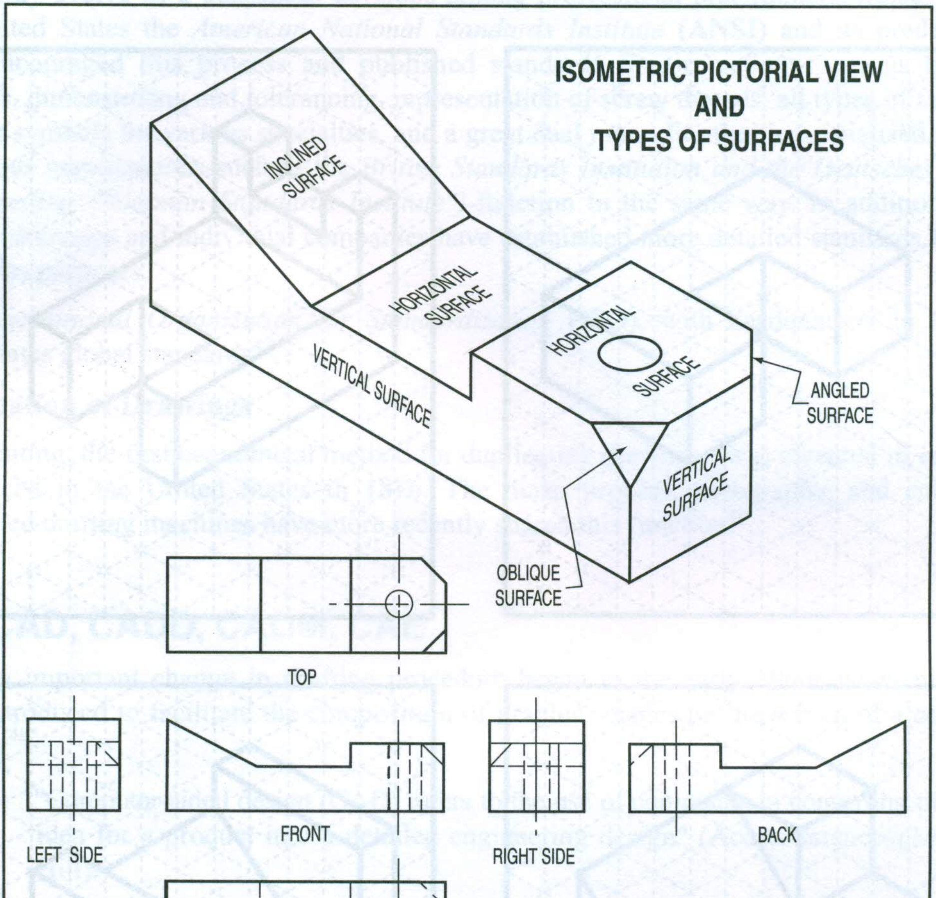








5.4 Orthographic, Isometric Views and Surfaces[54]



6

Chapter 6

Lessons in AutoCAD

Most of these lessons are filtered from http://www.we-r-here.com/cad/tutorials. However, the following lessons are edited and in few cases there are additional information, figures and other things.

6.1 Lesson 1

The X,Y co-ordinate system

Everything that you draw in AutoCAD is exact. It will be more accurate than you will ever need it to be. All objects drawn on the screen are placed there based on a simple X,Y co-ordinate system. In AutoCAD this is known as the World Co-ordinate System (WCS).

Angular Measurement

When drawing lines at an angle, you have to begin measuring the angle from 0 degrees, that is the positive X-axis (Isn't it 3 o'clock position of the hour-needle in the watch?). The rotation is counter clockwise.

6.1.1 Entering Points in AutoCAD

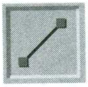
1. *ABSOLUTE CO-ORDINATES* - Using this method, you enter the points as they relate to the origin of the WCS. To enter a point just enter in the exact point as X,Y.
2. *RELATIVE CO-ORDINATES* - This allows you to enter points in relation to the first point you have entered. After you've entered one point, the next would be entered as @X,Y. This means that AutoCAD will draw a line from the first point to another point X units over and Y units up relative to the previous point.
3. *POLAR CO-ORDINATES* - You would use this system if you know that you want to draw a line a certain distance at a particular angle. You would enter this as @D<A. In this case, D is the distance and A is the angle. Example: @10<90 will draw a line 10 units straight up from the first point.

The three ways of entering co-ordinates shown above are the ONLY way AutoCAD accepts input. First decide which style you need to use, and then enter as shown. Remember that X is always before Y (alphabetical). Don't forget the '@' symbol when you are entering relative points. Any typing error or omission will give you results you don't want. If you make a mistake and need to see what you typed, press F2 to bring up the text screen and check your typing. (Press F2 to get back to your drawing.)

6.1.2 Icons, Keystrokes and Menus

Example: If you want to draw a line, you can do it a few ways:

1. At the command line type: LINE (or) L and press the ENTER key.



2. Select the line icon from the DRAW toolbar.
3. Select Draw > Line from the pull-down menu

Tips: *Easy way of drawing straight lines. Make the 'Ortho' tab 'on' (it's a tab at the bottom with others, click to turn it on or off). Then start drawing lines, select first point and then point the mouse anywhere in the desired direction, then give the distance (e.g. 4) and then press Enter.*

6.2 Lesson 2

6.2.1 Introduction to Drawing and Modify Commands

Start the LINE command and draw a line from **1,2** to **3,2** to **3,4** to **1,4** Press enter after each point. (*Remember to watch the command line as you do this.) For the last line, you can either type in **1,2** or **C** to close the line back to the first point you entered. You have just drawn a 2" square using **absolute co-ordinates.** Next draw a similar box using **relative co-ordinates.** Start the **LINE** command and begin at point 4.5,2. From there draw a line two units to the right by typing @2,0 (this means 2 units in the X direction, 0 units in the Y direction). Next type @0,2 then @-2,0 then @0,-2 to finish the box. (Remember to press enter after each point.) Draw the next box using **polar co-ordinate** input. Start the LINE command and begin at point 8,2 then enter. Type @1<45 to draw the first line. Next enter @1<135 then @1<225 then @1<315 (or C to close). What you have just done is drawn a line 1 unit long at 45 degree, then another at 135 degree and so on. Start the CIRCLE command and add a circle that has a center point at 7,6 with a radius of .75 (Watch the command line for instructions).

6.2.2 Basic Drawing Skills

Command	Keystroke	Icon	Menu	Result
Rectangle	RECTANGLE / REC	▭	Draw > Rectangle	Draws a rectangle after you enter one corner and then the second.
Multi Lines	MLINE / ML	No Icon	Draw > Multiline	Draw parallel lines based on the parameters you define.
Trim	TRIM / TR	-/--	Modify > Trim	Trims objects to a selected cutting edge.
Extend	EXTEND / EX	--/	Modify > Extend	Extends objects to a selected boundary edge.
Offset	OFFSET / O		Modify > Offset	Offsets an object (parallel) by a set distance.
Object Snaps	OSNAP / OS / F3	CLICK OSNAP	Tools > Object Snap Settings	Brings up the OSNAP dialog box.

Example:

6.2.3 TRIM command

Draw a line from **2,5** to **2,6.5** Draw another line from **1,6** to **3,6** You should now have two perpendicular lines. What you want to do is trim off the top of the vertical line and create a T.

Start the TRIM command. It will first ask for a cutting edge. Select the horizontal line and press <ENTER>. It will now ask for the object to be trimmed. Select the vertical line anywhere above the horizontal (cutting) line and press <ENTER> to finish the command.

This is what you saw on the command line:

Command: **TR** <enter> TRIM

Current settings: Projection=UCS, Edge=None

Select cutting edges ...

Select objects: <Select the Horizontal line>1 found

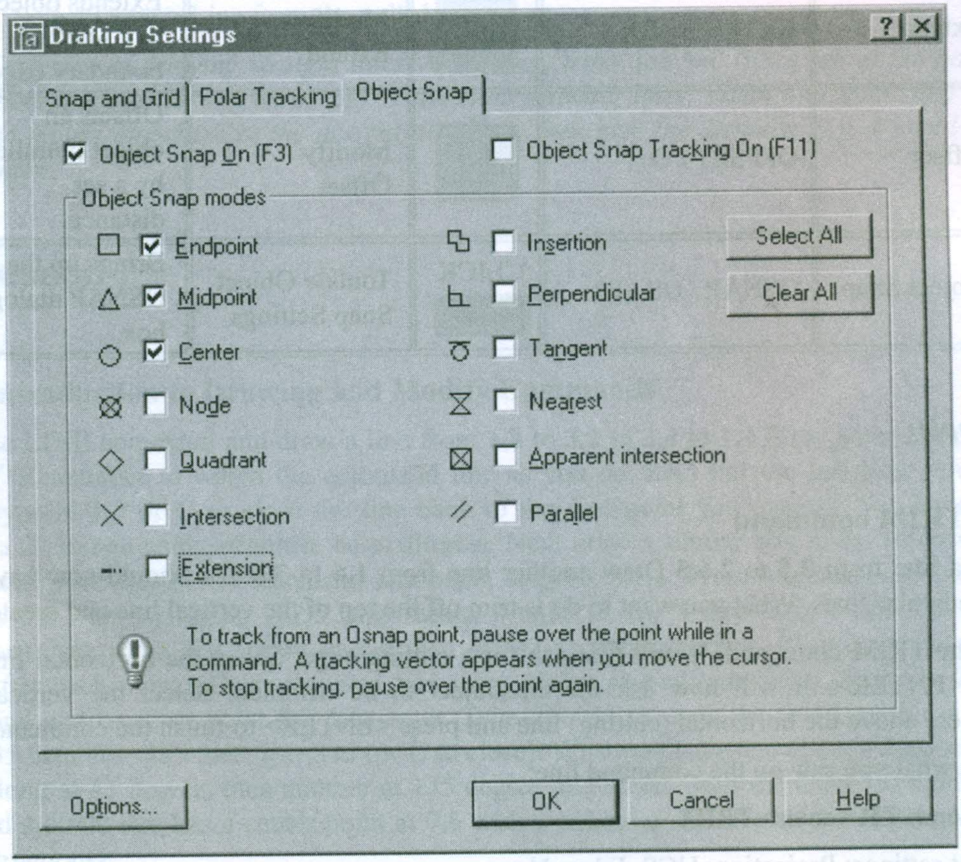
Select objects: <enter>

Select object to trim or shift-select to extend or [Project/Edge/Undo]: <Select the vertical line> Select object to trim or shift-select to extend or [Project/Edge/Undo]: <enter>

Once again, it is important to keep your eye on the command line as it will guide through most commands.

6.2.4 Object Snaps

Suppose you want to draw a line from the center of the circle to the middle of the vertical line you extended earlier. AutoCAD has a feature that makes this very easy. These are the Object Snaps (or Osnaps "Oh-Snaps"). Type OS <ENTER> . You will see this dialog box appear.



☑ Object Snap On (F3)

☐ Object Snap Tracking On (F11)

Object Snap modes

□ ☑ Endpoint	⊏ ☐ Insertion
△ ☑ Midpoint	⊾ ☐ Perpendicular
○ ☑ Center	○ ☐ Tangent
⊗ ☐ Node	⧗ ☐ Nearest
◇ ☐ Quadrant	⊠ ☐ Apparent intersection
× ☐ Intersection	// ☐ Parallel
--- ☐ Extension	

To track from an Osnap point, pause over the point while in a command. A tracking vector appears when you move the cursor. To stop tracking, pause over the point again.

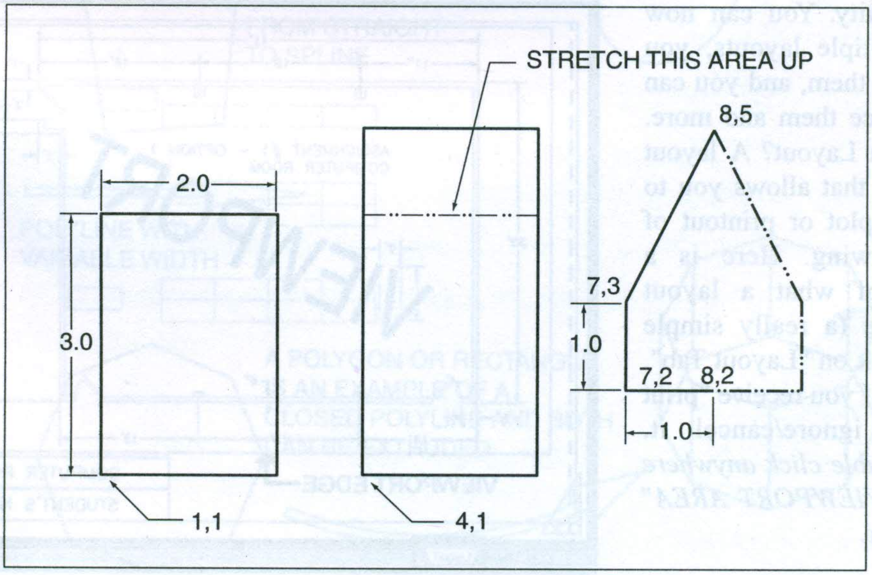
6.2.5 More Modifying Commands

All of these commands are ones that you will use on a regular basis.

Command	Keystroke	Icon	Menu	Result
Move	Move /M	✥	Modify > Move	Moves an object or objects
Copy	Copy /CP	⟳	Modify > Copy	Copies object(s) once or multiple times
Stretch	Stretch /S	◪	Modify > Stretch	Stretches an object after you have selected a portion of it
Mirror	Mirror /MI	◭◮	Modify > Mirror	Creates a mirror image of an object or selection set

Exercise:

Create a box as shown on the left, then move and stretch, and then on the right side, create a mirror image using the left half segment.

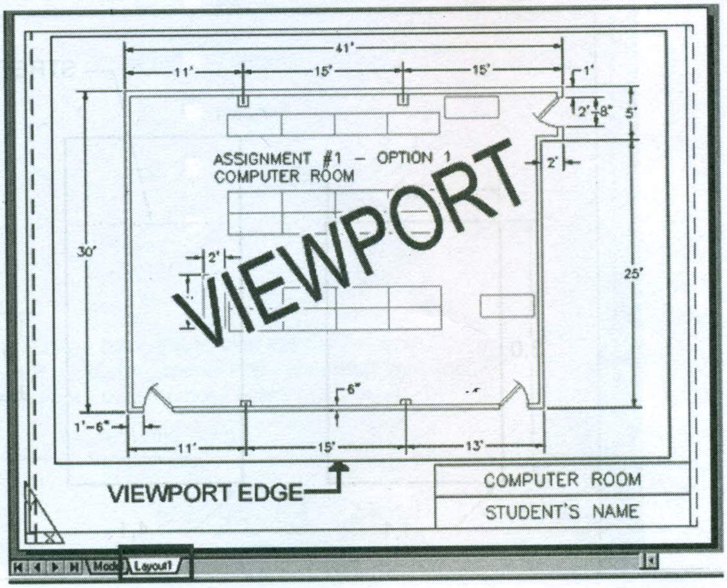


More Modifying Commands

Command	Keystroke	Icon	Menu	Result
Rotate	Rotate /RO	↻	Modify > Rotate	Rotates objects to a certain angle
Fillet	Fillet /F	╭	Modify > Fillet	Creates a round corner between two lines
Chamfer	Chamfer /CHA	⌜	Modify > Chamfer	Creates an angled corner between two lines
Array	Array /AR	⊞	Modify > Array	Creates a repeating pattern of the selected objects

6.2.6 Layout Tabs - Paper Space & Model Space

In AutoCAD there are two different workspaces: **model and Layout**. For now think of model space where you make your model, or draw. Think of the **Layout Tabs** as where you print your drawing from, or copy and output it to paper. Look at the images below to see a visual explanation of the concept. After AutoCAD R14, the term "Paper Space" was replaced by "Layout". These terms are interchangeable. The release of AutoCAD 2000 brought other enhancements to this functionality. You can now have multiple layouts, you can name them, and you can re-sequence them and more. What is a Layout? A layout is a page that allows you to set up a plot or printout of your drawing. Here is a sample of what a layout looks like (a really simple one). Click on "Layout Tab", and then if you receive "print option", ignore/cancel it. Then *Double click anywhere on the "VIEWPORT AREA" to activate.*



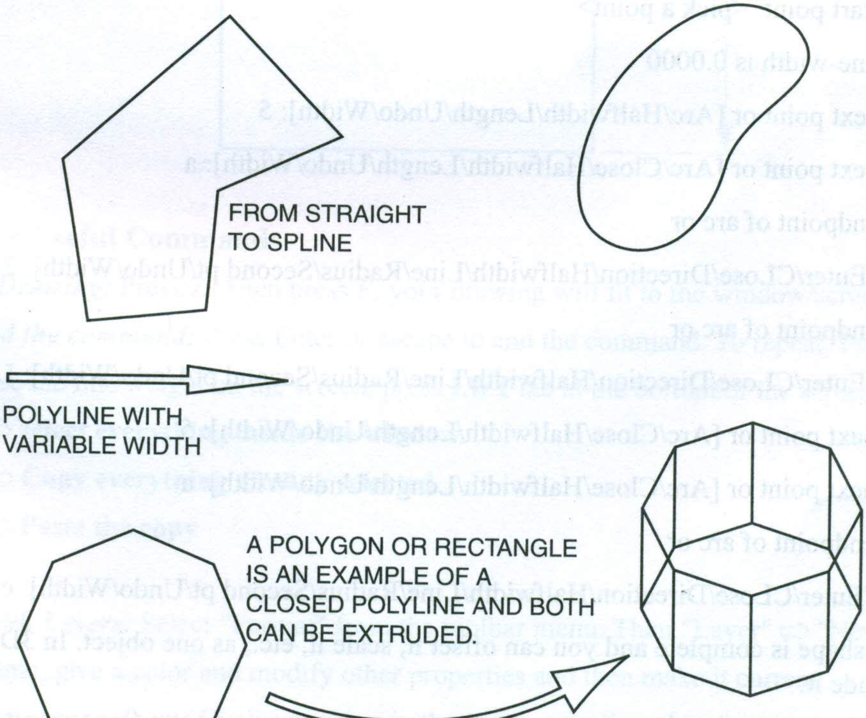
6.2.7 Polylines

A polyline is an object in AutoCAD that consists of one or more line (or arc) segments. A rectangle is an example of a polyline that you are already familiar with. As you've seen, it is one object that can be modified and worked with easier than four separate lines.

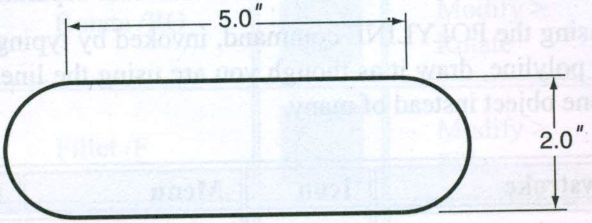
Polylines are created using the POLYLINE command, invoked by typing PL at the command line. To draw a simple polyline, draw it as though you are using the line command. The only difference is that it is one object instead of many.

Command	Keystroke	Icon	Menu	Result
Polyline	Pline / PL		Draw > Polyline	Creates a polyline of arcs and/or lines.
Polyline Edit	Pedit / PE		Modify > Polyline	Edits polyline objects

Examples of Polyline



Below is a sample drawing you can reproduce using a polyline. First, think about how you would draw it using lines, arcs and circles.



Here's how you draw it using one polyline:

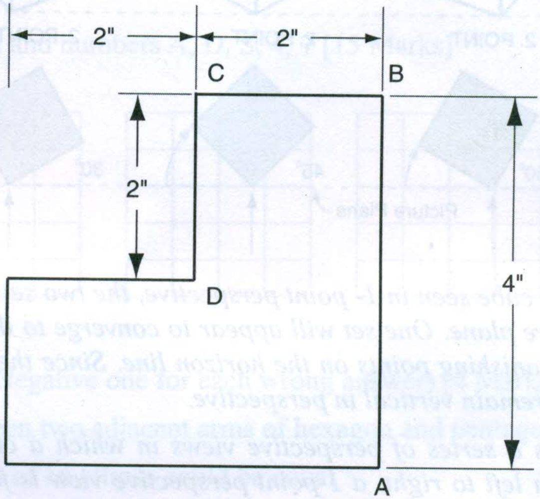
```
Command: <ortho on>
         (click the ortho tab)

Command: pl
         (PLINE)

Specify start point: <pick a point>

Current line-width is 0.0000

Specify next point or [Arc/Halfwidth/Length/Undo/Width]: 5

Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: a

Specify endpoint of arc or

[Angle/CEnter/CLose/Direction/Halfwidth/Line/Radius/Second pt/Undo/Width]: 2

Specify endpoint of arc or

[Angle/CEnter/CLose/Direction/Halfwidth/Line/Radius/Second pt/Undo/Width]: Line

Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 5

Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: a

Specify endpoint of arc or

[Angle/CEnter/CLose/Direction/Halfwidth/Line/Radius/Second pt/Undo/Width]: cl
```

Now the shape is complete and you can offset it, scale it, etc., as one object. In 3D, you could also extrude it.

6.3 Lesson 3

6.3.1 Finding Area of Any Shape

This is a neat feature. Draw the figure below. Now, select **'Tools' ⇨ 'inquiry' ⇨ 'Area'** Then select the points A, B, C, D, E, F and at the end A. Then Press Enter. You should see the answer for the area and the perimeter.



6.3.2 Some Useful Commands

Zoom the Drawing: Press Z. Then press E. your drawing will fit to the window/screen.

Repeat/End the command: Press Enter or escape to end the command. To repeat, Press Enter

LWT: To see the line weight on the screen, press LWT tab at the bottom of the screen.

Ctrl + A ⇨ select everything inside the window.

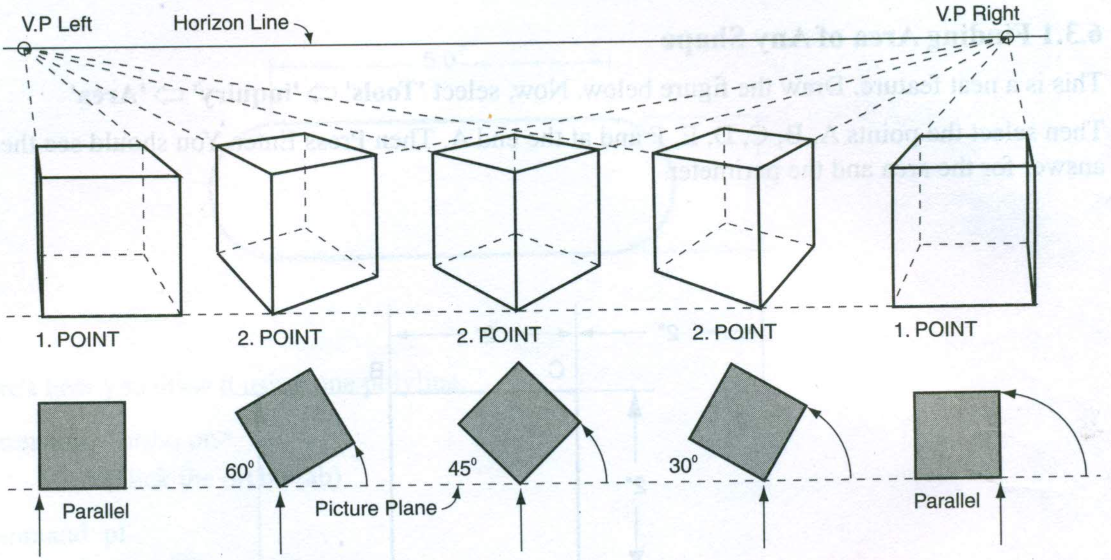
Ctrl + C ⇨ Copy everything already selected

Ctrl + V ⇨ Paste the copy

Working with Layers: Select "Format" from the toolbar menu. Then "Layer" ⇨ "New" Select a Name, give a color and modify other properties and then make it current

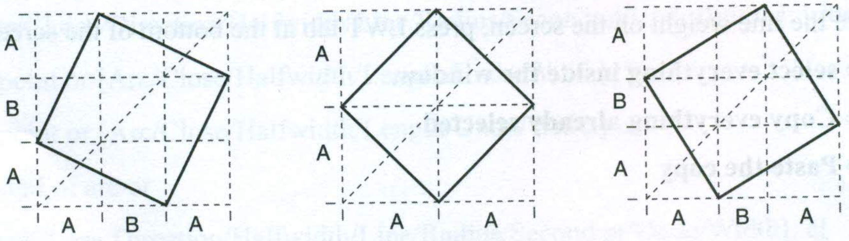
To add necessary toolbars: Click anywhere in the existing toolbar, then "customize", then select the tab for "Toolbars"

Drawing, a Creative Process[56] (Francis D.K. Ching, 1990)



When we rotate the cube seen in 1- point perspective, the two sets of horizontal lines are both obique to the picture plane. One set will appear to converge to the left, the other to the right, thus we have two vanishing points on the horizon line. Since the verticals are parallel to the picture plane, they remain vertical in perspective.

Illustrated above is a series of perspective views in which a cube rotates about a forward vertical edge. From left to right, a 1-point perspective view is followed by a sequence of 2-point perspective views. The cube finally rotates back to where its front face is parallel to the picture plane. It is thus seen in 1-point perspective.



For the purpose of sketching a 2-point perspective view, we can build on our familiarity with a 1-perspective cube. We must first understand that a square can be rotated at any angle and be inscribed within a larger square, as shown above. In each case, note that the inscribed square touches the larger square at points equally distant from each corner.

Chapter 7

Sample Questions and Exercises

7.1 Some Sample Questions to Practice

1. Draw the following letters and numbers A, D, S, 4, 7 [15 Marks]

2. Indicate True or False (Negative one for each wrong answer) [4 Marks]

   a) Included angles between two adjacent arms of hexagon and pentagon are equal

   b) Minor and Major axes of an ellipse could be equal

3. Circle all the correct answers for the following [4 Marks]

   a) Included angle between two adjacent arms of Octagon is

   (i) 145 (ii) 135 (iii) 130 (iv) 155 (v) none of these

   b) Horizontal cut of a Pyramid produces a

   (i) circle (ii) rectangle (iii) square (v) none of these

4. Draw development of a solid box that is 1.5 inches high, 0.75 inches wide and one inch long (Draw to the scale and indicate the sides) [5 Marks]

5. Indicate True or False (Negative one for each wrong answer) [4 Marks]

   c) Base of a Pyramid could not be a rectangle

   d) Front view of a cylinder and prism could not be the same

6. Circle all the correct answers for the following [4 Marks]

   c) Included angle between two adjacent arms of a Pentagon is

   (i) 145 (ii) 135 (iii) 130 (iv) 108 (v) none of these

   d) Horizontal cut of a 'Cone' produces a

   (i) circle (ii) rectangle (iii) square (v) none of these

7. What are the six primary Orthographic views?

8. How many Orthographic views are needed to adequately depict the necessary information to illustrate a cylinder? (Hint: only two Orthographic views are needed).

9. To complete the drawing of a cylinder and a sphere how many dimensions are needed?

   Ans: The diameter of the cylinder and its length are the only dimension information needed to complete the drawing. A sphere only needs the diameter. It is the same from all angles and remains a perfect circle in the isometric drawing

10. What is the meaning of the word geometry?

11. What do you know about Mr. Euclid?

12. Define the following-Point, Line, Plane, and Acute, Right, Obtuse, Oblique angles.

13. Define Parabola and Ellipse.

14. Define the System International [S I].

15. What is the meaning of the word Isometric?

16. Who gave the first correct explanation of vision, showing that light is reflected from an object into the eye, not from eye to object?

17. Who gave the first exposition of descriptive geometry and did the formalization of orthographic projection?

18. What are the two types of "Obliques"? What is the major difference between them?

19. What are the types of "Perspectives"?

20. What is drawn as ellipses on receding planes? (Ans. Circles in Oblique)

21. Describe various line types with figures.

22. Draw examples for conventional short and long break lines? When you should use the break lines?

23. Show the three ways of Dimensioning circles?

24. What should be the width and length ratio for a standard arrowhead?

25. Define "ISO", and "ANSI".

26. Define CAD, CADD, CADM, and CAE.

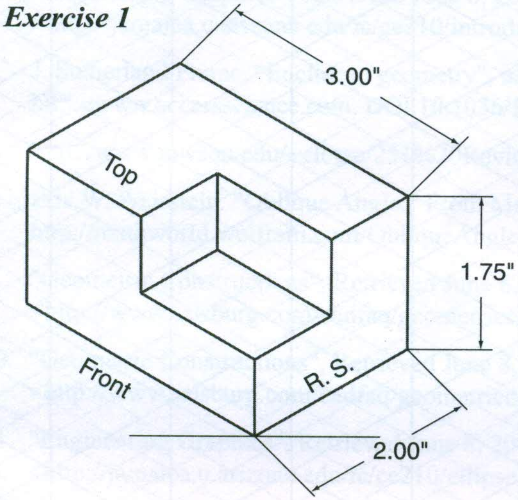
27. If you take a piece of paper (e.g. A4 size offset paper), and then hold it in front of you as

to put on a clip board (i.e. in vertical position), then draw with neat sketch the front view, the top view and the side view. How many dimensions do you need to describe these views? Regarding the top view and the side view, are they same?

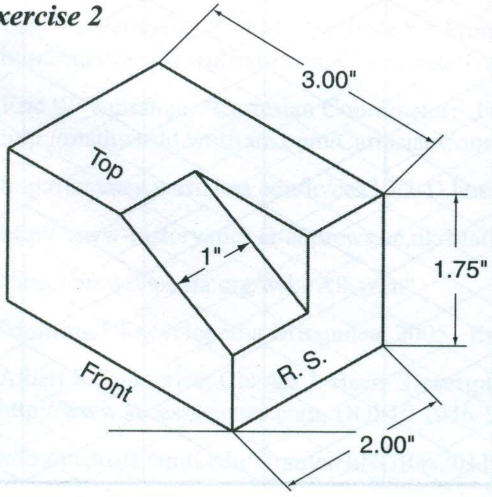
7.2 Exercises on Generating Orthographic Views from Isometric Views

Draw Front view, Right side view and Top view for the following figures

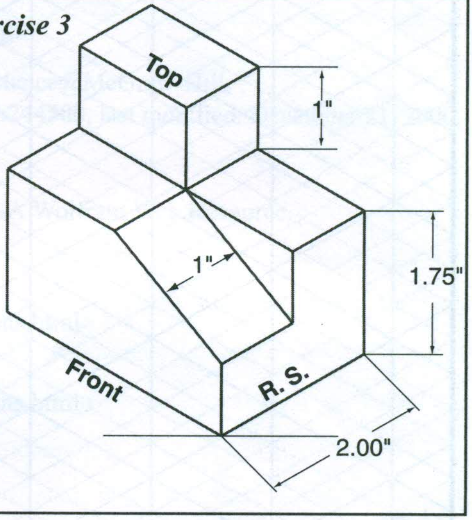
Exercise 1



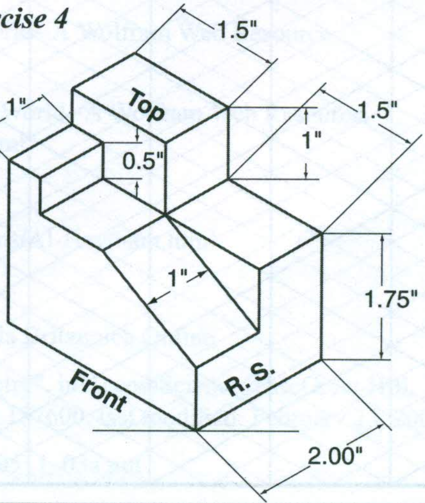
Exercise 2



Exercise 3



Exercise 4



7.3 Isometric Grid Work Sheet

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